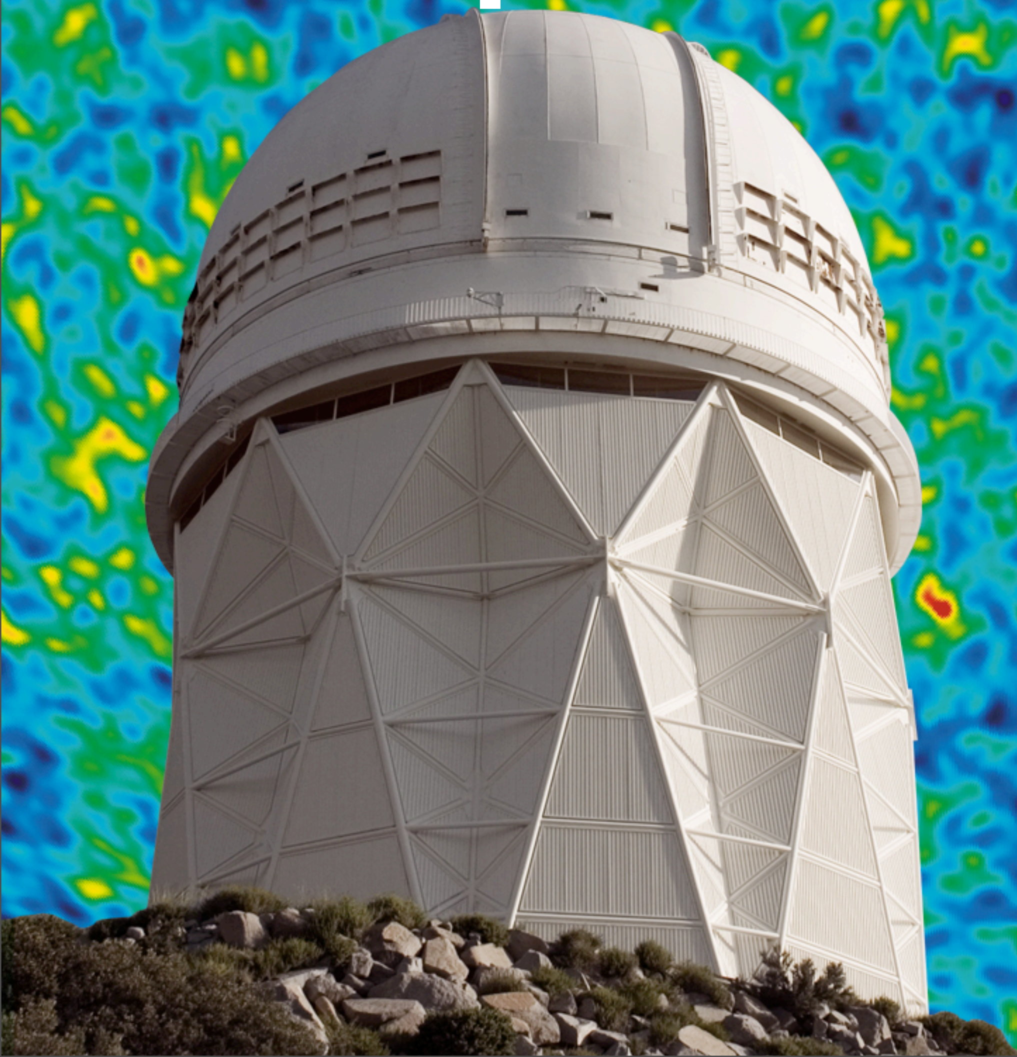
BigBOSS: The Ground-Based Stage IV BAO Experiment



Submitted to Astro2010 Decadal Survey
April, 2009

Presented by
David Schlegel

BigBOSS: The Stage IV BAO Experiment
The Questions

Physics beyond the standard model

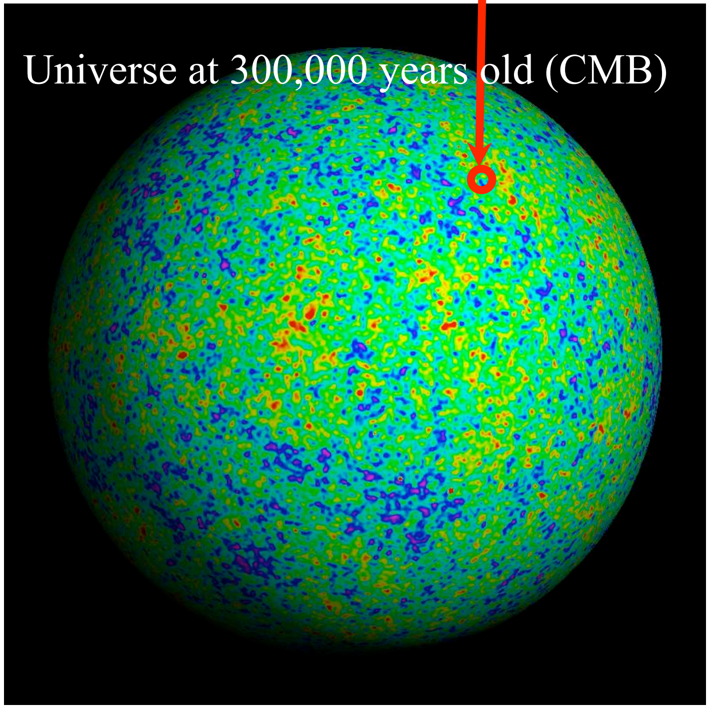
Precision dark energy probe from BAO scale

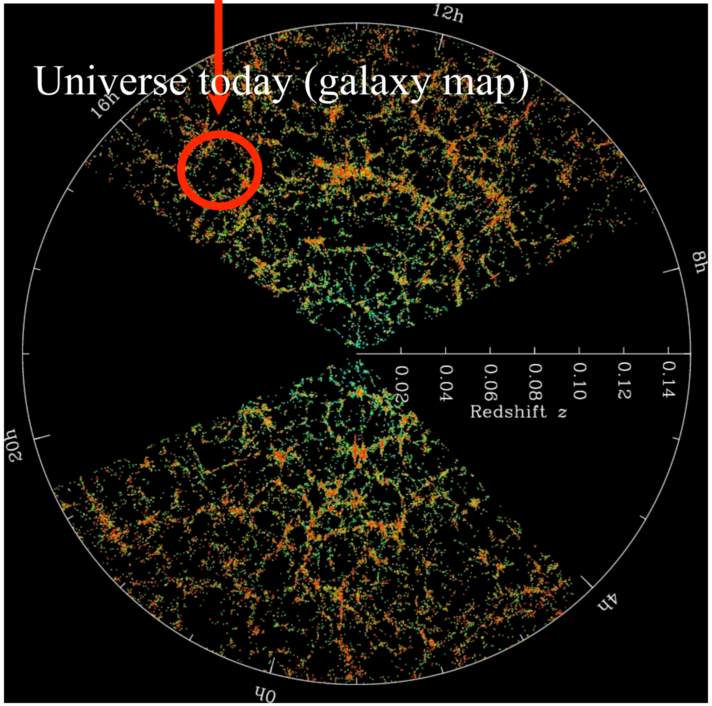
Inflation probe from non-gaussian fluctuations

- Better than Planck or JDEM

These fluctuations of 1 part in 10^5 gravitationally grow into...

...these ~unity fluctuations today





BigBOSS: The Stage IV BAO Experiment
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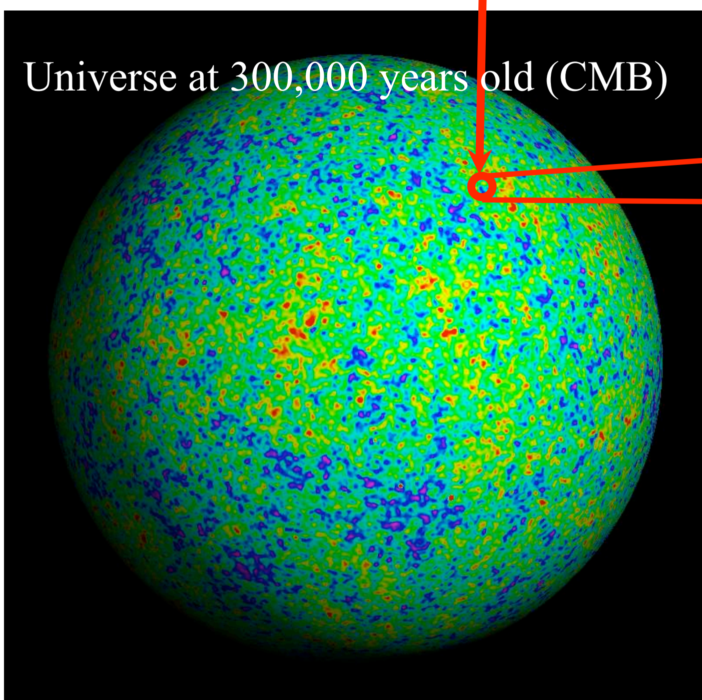
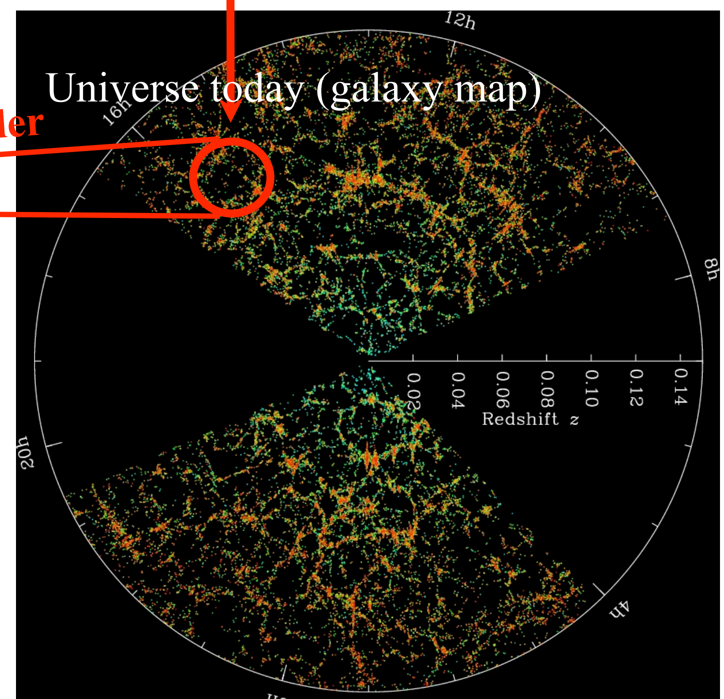


standard ruler



The Ground-Based Stage IV BAO Experiment
BigBOSS

BigBOSS: The Stage IV BAO Experiment

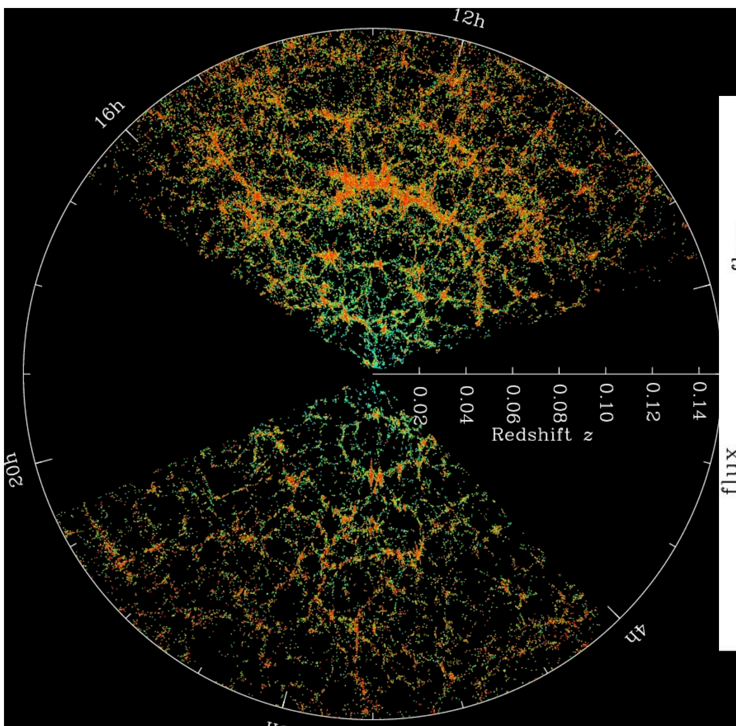
Kitt Peak 4-m instrument: 5000-fiber spectrograph in 3 deg field

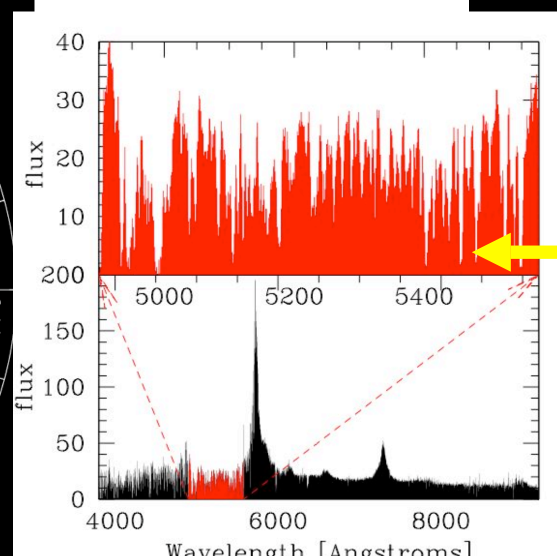
- ➙ Blue (3400-5500 Å) optimized for QSO Ly
- ➙ Red/IR (8000-11300 Å) optimized for emission lines

Simultaneous spectroscopic surveys from 2014-2024

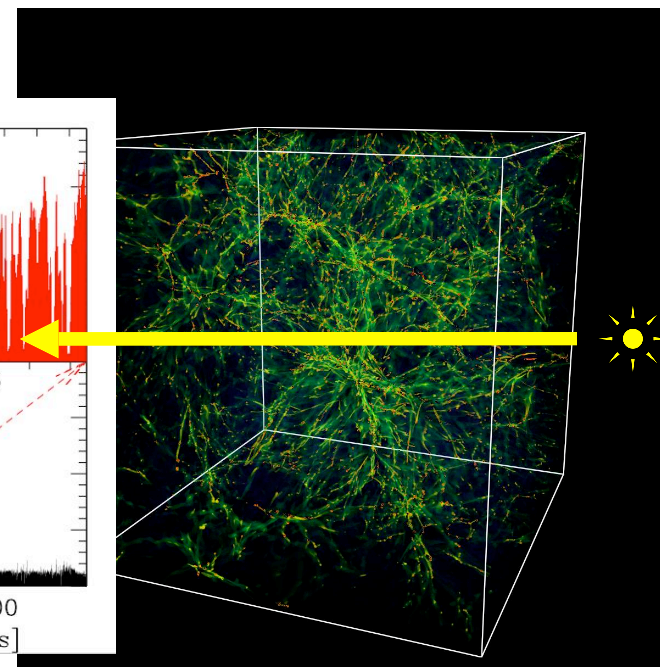
- ➙ BAO from 50 million galaxies at $0.2 < z < 2.0$
- ➙ BAO from 1 million QSOs at $1.8<z<3$

Galaxy map





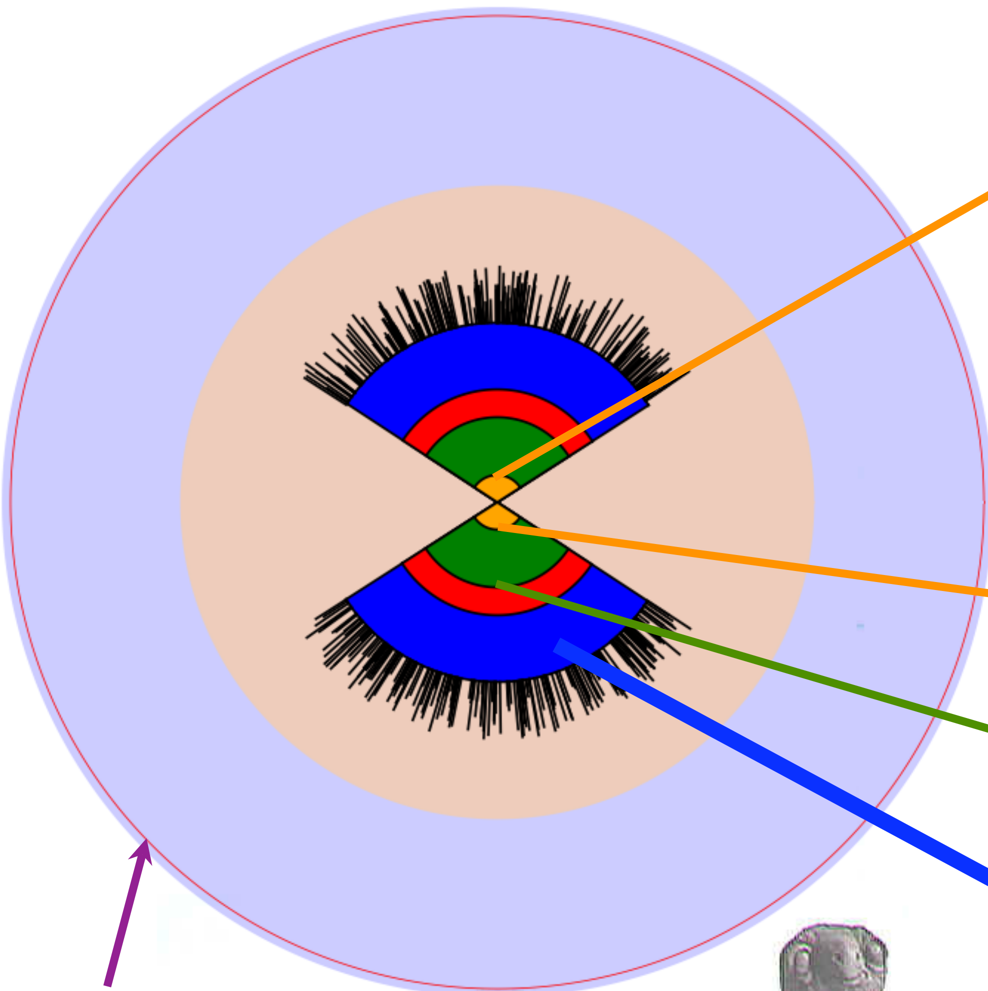
QSOs as back-light to hydrogen gas



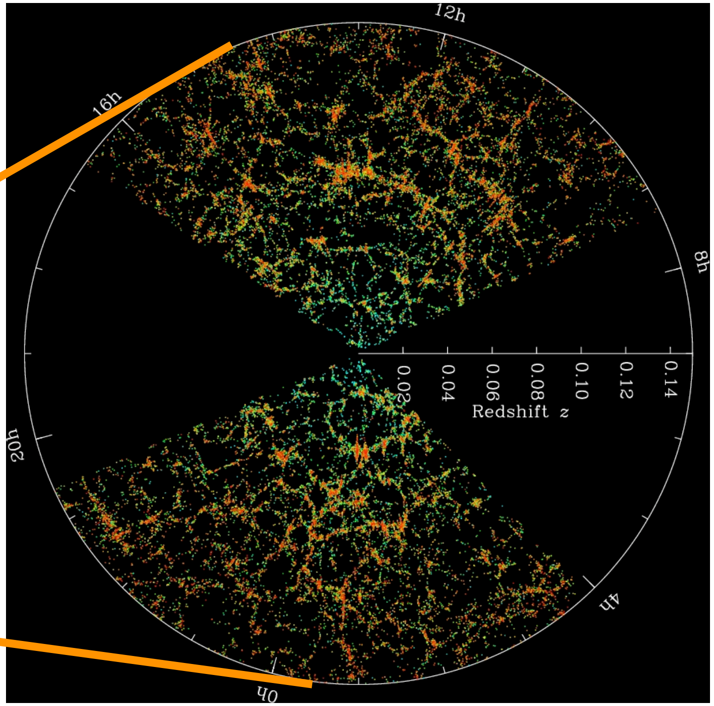
BigBOSS: The Stage IV BAO Experiment Science Reach

Sensitivity to new physics scales as volume surveys -- # of modes

Our observable Universe



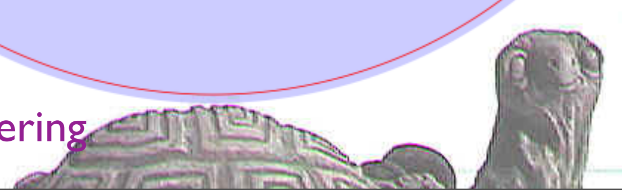
Volume mapped by SDSS + SDSS-II



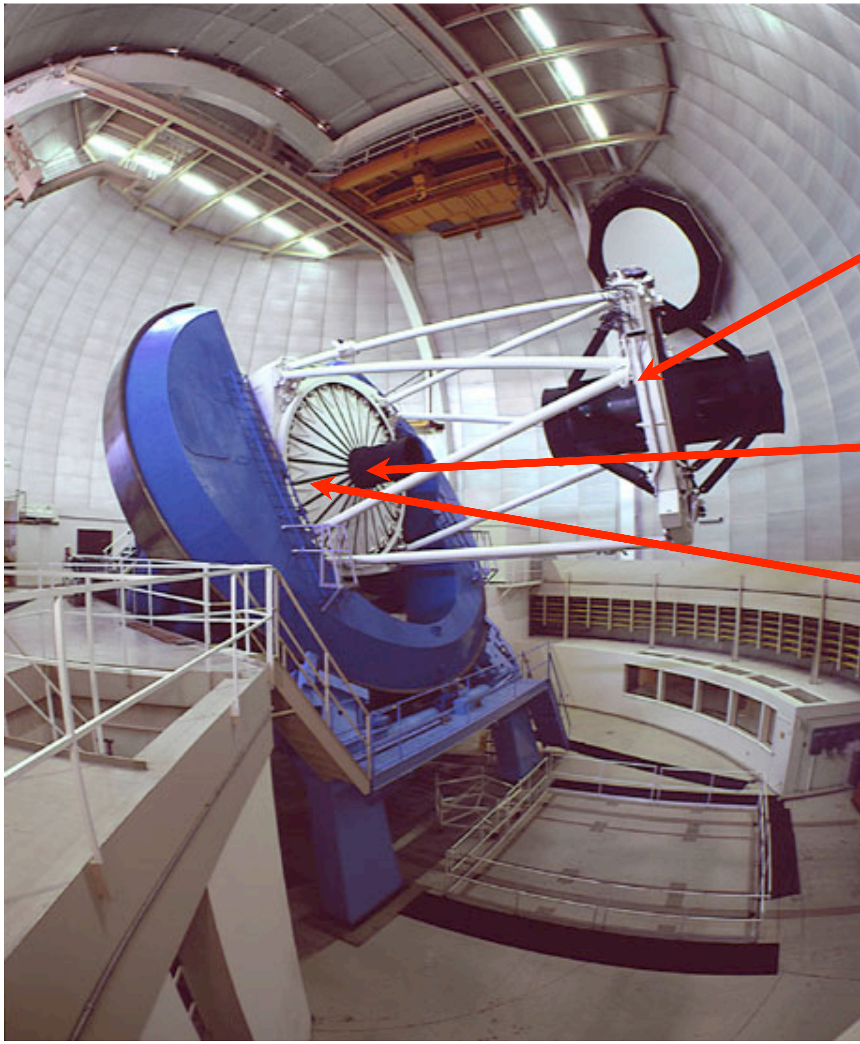
Volume to be mapped by SDSS-III/BOSS (ca. 2015)

BigBOSS @NOAO

Surface of last scattering



@ Kitt Peak 4-m



New 2-m secondary

New 3-element corrector

3° f/5 focal plane!!

BigBOSS: The Stage IV BAO Experiment
Spectrograph Design

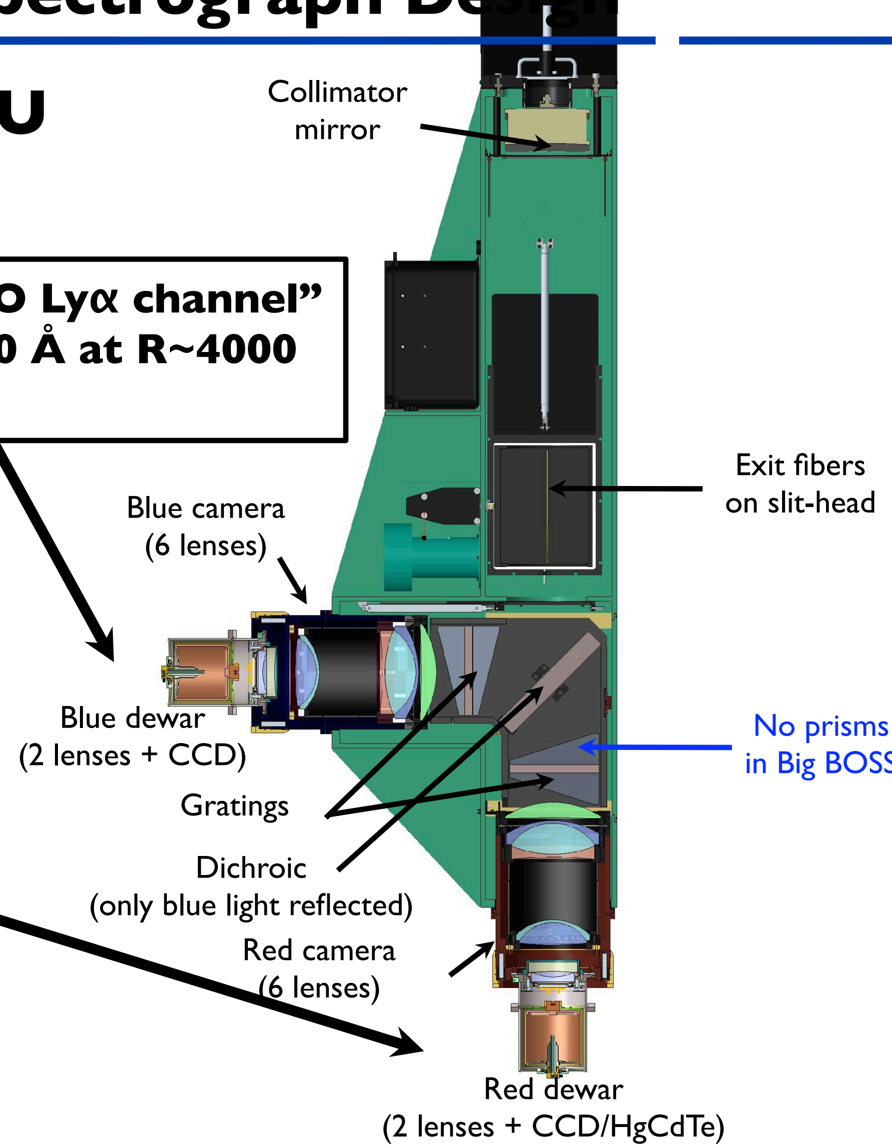
Notional design from JHU

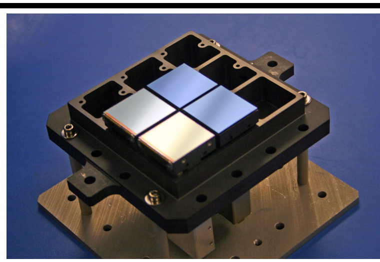
Based upon BOSS/WFMOS design
Bench-mounted (stability!)

Blue "QSO Lyα channel"
3400-5500 Å at R~4000
e2v CCDs

Visible "supernova channel"
5500-8000 Å at R~3500
LBNL CCDs (not shown)

Red "galaxy channel"
8000-11,300 Å at R~5000
LBNL CCDs + Teledyne HgCdTe





The Ground-Based Stage IV BAO Experiment
BigBOSS

BigBOSS: The Stage IV BAO Experiment Science Reach

	BOSS (Stage III)	BigBOSS-North (Stage IV)	JDEM (Stage IV)	BigBOSS-N+S (Stage IV)
Redshift range	**0<z<0.7**	**0<z<3.5**	**0.7<z<2.0**	**0<z<3.5**
Sky Coverage	10000 deg^2	14000 deg^2	20000 deg^2	24000 deg^2
Wavelength Range	360-1000 nm	340-1130 nm	1100–2000 nm	340nm–1130 nm
Spectral Resolution	1600-2600	2300-6100	200	2300-6100
DETF FoM	57	175	250	286
DETF FoM w/Stage III	**107**	**240**	**313**	**338**

Direct comparison with
same FoMSWG priors

Stage IV BAO can be done from the ground over full redshift range

BigBOSS is Low Risk

- [O II] redshift surveys well-established to z=1.5 (DEEP, zCOSMOS)
- [O II] doublet is unique signature
- Color cuts select desired redshift distribution
- Avoids source confusion of slitless grism (i.e., JDEM)

[O II] redshift survey simplest approach to high-z BAO

Question #1

Q: What fraction of the observing time do you expect to be devoted to the BigBOSS survey during its operation? What information do you have on the likelihood that the US community will approve of devoting a huge fraction of the 4m dark time the BigBOSS science for 2015-2021? What is the process for approving this allocation of resources?

- Dark-time for 10 years (6 in North + 4 in South) for 50 million galaxies
  - *Move instrument after completion of DES*
- Assumes 50% weather loss, and 60% observing speed relative to good conditions
- Exposure time tuned to z=2.0 limit (8σ)
- Possible descope to z=1.6 using 100 nights/yr (equivalent to the DES utilization of CTIO), yielding DETF FoM ~15% lower

The Ground-Based Stage IV BAO Experiment
BigBOSS

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- Total survey requires ~600 clear nights
- Dark-time for 10 years (6 in North + 4 in South) for 50 million galaxies
  - *Assumes 50% weather loss, 60% observing speed relative to good*
  - *Move instrument after completion of DES*
  - *Exposure time tuned to z=2.0 limit (8σ)*
- Possible descope to z=1.6 using 100 nights/yr (equivalent to the DES utilization of CTIO), yielding DETF FoM ~15% lower

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- There are seven 4-m class facilities in the US OIR System: Palomar 5-m, SOAR 4.2-m, KPNO 4-m, CTIO 4-m, WIYN 3.5-m, ARC 3.5-m, and Lowell 4.2-m (available in 2 years)

- KPNO 4-m and CTIO 4-m can be converted to 3-degree field (with identical optical elements)

BigBOSS can be fully realized with 1/7th of U.S. 4-m time

The Ground-Based Stage IV BAO Experiment

BigBOSS

Question #1

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- NOAO developed plan for <6m telescopes through ReSTAR committee (Renewing Small Telescopes for Astronomical Research)
- This committee's recommendations call for the specialization of the 2-4 meter class telescopes: *"Specialization will provide a more limited set of observing capabilities on each telescope but should preserve a breadth of capability across the ReSTAR System."*
  - BigBOSS instrument = most ambitious low- and mid-resolution spectrograph: 5000 fibers spanning 340-1150 nm

BigBOSS consistent with ReSTAR recommendations

Question #1

Q: What fraction of the observing time do you expect to be devoted to the BigBOSS survey during its operation? What information do you have on the likelihood that the US community will approve of devoting a huge fraction of the 4m dark time the BigBOSS science for 2015-2021? What is the process for approving this allocation of resources?

Possible processes:

- NOAO issues a call similar to that which selected DES
- BigBOSS pays for displacement time
  — *ReSTAR committee endorses as means to obtaining new capabilities*
- BigBOSS competitively selects from public and private 4-m

BigBOSS spectrographs would not be left idle on a shelf!

Question #1

Q: What fraction of the observing time do you expect to be devoted to the BigBOSS survey during its operation? What information do you have on the likelihood that the US community will approve of devoting a huge fraction of the 4m dark time the BigBOSS science for 2015-2021? What is the process for approving this allocation of resources?

Community access:

- At the NOAO 4-m telescopes, the community would have direct access to the capability in four ways.

1. Participation in the collaboration
2. NOAO TAC awarding nights
3. NOAO TAC awarding fraction of fibers, piggyback BigBOSS survey
4. Legacy value of the survey data

BigBOSS would be unique community capability

Question #2

Q: Can you provide a detailed cost estimate, including operations?

What is included in the operations cost estimate?

Which parts of the path from data to science are not included, and where will that funding come from?

- **Four year development before start of operations**
- **BigBOSS relies heavily on BOSS heritage**
  - As-built expenses for spectrographs, CCDs, electronics, fibers
- **Telescope, instrument operations + admin costs provided by KPNO**
  - Additional personnel for instrument
- **Pipeline development based upon BOSS**
  - Additional effort before start
- **Data reduction + distribution based upon SDSS-III**
  - Through final data release

BigBOSS has cost heritage from BOSS + KPNO ops

More detail in Astro2010 written response

Question #2

Q: Can you provide a detailed cost estimate, including operations?

What is included in the operations cost estimate?

Which parts of the path from data to science are not included, and where will that funding come from?

- **Data analysis not included beyond the reduction of the data to 1-D spectra, redshifts and object classification**
  - *SDSS-III/BOSS model to be followed*
  - *Member universities commit funds for the project buy-in and science*
- **Long-term data stewardship not included**

Question #2

BigBOSS Total Cost

- **Construction funded by DOE + international partners**
  - *Major participation by international partners for key technologies*
- **Operation costs to be provided by Universities + NSF**
  - *Telescope operations included in budget*

BigBOSS Cost Breakdown

WBS	Description	Cost by WBS	Offsets: Major in kind contributions		Offsets: University Contributions
1.0	Project Management & System Engineering	5.1			5.0
2.0	Spectrographs and Instrument Electronics	30.9	10.6	France	
3.0	Fiber System with Positioners	5.4	4.8	China	
4.0	Optics	8.4			
5.0	Contingency	15.0			
6.1	Instrument Operations (6 years)	10.5			5.0
6.2	Data Operations (7.5 years)	9.6			
	Total Project Cost -- Construction + Ops:	**84.9**			
	Total Contributions:	25.4			
	Total DOE Cost -- Construction only:	**44.4**			
	Total DOE Cost -- Ops. only:	**15.1**			

More detail in Astro2010 written response

Question #2

BigBOSS Total Cost - Descope Option

- **Same instrumentation except that the NIR detectors are omitted**
  - — **Saves $9.7M in NIR detector cost**
  - — **Science descoped from z<2.0 to z<1.6**

<table>
<tr><th colspan="6">BigBOSS Cost Breakdown -- with Descope of NIR Detectors</th></tr>
<tr><th rowspan="2">WBS</th><th rowspan="2">Description</th><th rowspan="2">Cost by WBS</th><th colspan="3">Offsets</th></tr>
<tr><th colspan="2">Major in kind contributions</th><th>University Contributions</th></tr>
<tr><td>1.0</td><td>Project Management & System Engineering</td><td>5.1</td><td></td><td></td><td rowspan="4">5.0</td></tr>
<tr><td>2.0</td><td>Spectrographs and Instrument Electronics</td><td>20.9</td><td>10.6</td><td>France</td></tr>
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<tr><td>4.0</td><td>Optics</td><td>8.4</td><td></td><td></td></tr>
<tr><td>5.0</td><td>Contingency</td><td>12.0</td><td></td><td></td><td></td></tr>
<tr><td>6.1</td><td>Instrument Operations (5 years)</td><td>8.8</td><td></td><td></td><td rowspan="2">5.0</td></tr>
<tr><td>6.2</td><td>Data Operations (6.5 years)</td><td>8.2</td><td></td><td></td></tr>
<tr><td></td><td>Total Project Cost -- Construction + Ops:</td><td>68.8</td><td colspan="3" rowspan="4"></td></tr>
<tr><td></td><td>Total Contributions:</td><td>25.4</td></tr>
<tr><td></td><td>Total DOE Cost -- Construction only:</td><td>31.4</td></tr>
<tr><td></td><td>Total DOE Cost -- Ops. only:</td><td>12.0</td></tr>
</table>

More detail in Astro2010 written response

The Ground-Based Stage IV BAO Experiment
BigBOSS

Question #2

WBS Level 2	3	4	Description	Total	Basis of Estimate
1			**Construction Project Management and System Engineering**	**5.1**	
1	**1**		Project Management (includes Administrative Support)	1.9	DES and Daya Bay, LBNL Labor Rates
1	**2**		Systems Engineering and Quality Assurance	3.2	DES and Daya Bay, LBNL Labor Rates

The Ground-Based Stage IV BAO Experiment

BigBOSS

Question #2

2	3	4	Description	Total	Basis of Estimate
2			**Spectrographs and Instrument Control Electronics**	**30.9**	
2	1		Spectrograph Optics and Structure (x10)	**10.7**	
2	1	1	Management	0.68	
2	1	2	Systems Engineering	1.67	
2	1	3	Structure	0.68	
2	1	4	Slithead	0.14	
2	1	5	Collimator Assembly	0.56	WFMOS Spectrograph Proposal and BOSS actuals
2	1	6	Hartmann Doors and Shutter	0.12	
2	1	7	Central Optics	1.62	
2	1	8	Blue Camera	1.46	
2	1	9	Visible Camera	1.29	
2	1	A	Red Camera	1.29	
2	1	B	Controller	0.47	
2	1	C	Integration and Test	0.72	
2	3		Detector Assy 1	**4.00**	
2	3	1	Dewar and Vacuum System	2.30	Engineering Estimate, BOSS actual
2	3	2	Detector [4kx4kx15u e2v]x10	1.30	Vendor Quote from e2v
2	3	3	Front End Electronics [CRIC 5.0 - CLIC 5.0]	0.40	Engineering Estimate, SNAP Prototype Build
2	4		Detector Assy 2	**2.60**	
2	4	1	Dewar and Vacuum System	1.00	Engineering Estimate
2	4	2	Detector [4kx4kx15u LBNL]x10	1.20	Vendor Quote from MSL
2	4	3	Front End Electronics [JDEM CCD F/E module]	0.40	Engineering Estimate, SNAP Prototype Build
2	5		Detector Assemblies 3	**11.80**	
2	5	1	Dewar and Vacuum System	0.50	Engineering Estimate
2	5	2	Detectors [2 each 2kx2kx18u Teledyne +2 each 4kx4kx15u LBNL]x10	10.80	Vendor Quotes from Teledyne and MSL
2	5	3	Front End Electronics [JDEM SIDECAR module]	0.50	Vendor Quote from Teledyne
2	6		Digital Electronics System	**1.80**	
2	6	1	Positioner Control Elect. with Camera Interface	0.10	Engineering Estimate
2	6	2	Science Data Processing and Control Electronics	0.20	Engineering Estimate, SNAP Prototype Build
2	6	3	Software	1.50	Engineering Estimate, BOSS actual

Question #2

2 3 4	Description	Total	Basis of Estimate
3	**Fiber System with Positioners**	**5.4**	
3 1	Fiber Assembly [block w/ 500 150u fibers]x10	1.2	Vendor quote (catalog item), BOSS actual
3 2	Positioner Assemblies	3.8	Engineering Estimate, Prototype Build Invoices
3 3	Fiber Support Tray System	0.4	Engineering Estimate
4	**Optic**	**8.4**	
4 1	Upper Mechanical Structure	0.9	Engineering Estimate from KPNO
4 2	Secondary Mirror	3.5	Quote from U. Arizona Optical Sci.
4 3	Fiber Position Camera Assembly	0.1	Fairchild Off-the-Shelf Product
4 4	Lower Mechanical Structure	0.9	Engineering Estimate from KPNO
4 5	Cassegrain Cell Assembly	0.8	Engineering Estimate from KPNO
4 6	ADC Assembly	0.8	Engineering Estimate from KPNO
4 7	Focal Plane Assembly	1.4	Engineering Estimate
4 7 1	Mounting Plate and Structure		Engineering Estimate
4 7 2	Guider Modules		Semi-custom designs & built around a standard CCD
4 7 3	Auto Focus Modules		
5	**Contingency**	**15.0**	Based on 30% on all construction costs. Contingency on Ops included in 7.0

The Ground-Based Stage IV BAO Experiment

BigBOSS

Question #2

2	3	4	Description	Total	Basis of Estimate
6			**Pipeline and Operations**	**20.1**	
6	**1**		Instrument Operations	**10.5**	KPNO estimates
6	**1**	**1**	Spectrograph Operations (including dewars, detectors)	3.0	
6	**1**	**2**	Associated Computers	1.5	
6	**1**	**3**	Non-Spectrograph Hardware	1.5	
6	**1**	**4**	Telescope Operations	3.0	NSF/NOAO
6	**1**	**5**	Management/Admin Support	1.5	
6	**2**		Data Management Budget	**4.5**	SDSS running costs
6	**2**	**1**	Science Archive Servers and Mirror	0.8	
6	**2**	**2**	Maintenance and Facility Support	1.4	
6	**2**	**3**	Data Archivist and Coordinator	0.8	
6	**2**	**4**	Catalog Archive Administrators and Licensing	0.6	
6	**2**	**5**	Software Development	0.9	
6	**3**		Data Reduction	**5.1**	Estimate, based on BOSS projected
6	**3**	**1**	Project Management	0.6	
6	**3**	**2**	Data Reduction and Packaging	1.0	
6	**3**	**3**	Code Development	2.2	
6	**3**	**4**	Target Selection	0.8	
6	**3**	**5**	Computing Hardware, Support and Licensing	0.5	

The Ground-Based Stage IV BAO Experiment

BigBOSS

Question #3

Q: What line flux sensitivity do you expect as a function of wavelength in a one-hour exposure (for all redshifts in the survey)? What comoving number density of galaxies as a function of redshift will the survey sample?

Three samples:

- **LRG's:**

—Selected to z<1

—Efficient BAO tracers due to large bias

- **SFG's:**
  - — Selected 0.7<z<2.0 at source density of dn/(dz deg^2)=2000
  - — Comoving number density of 3.4x10^{-4} (h/M pc)^3
  - — Redshifts from [OII] line emission at resolution R~5000
  - — Single-line minimal detectable line flux (MDLF) of 2.5x10^{-17}
- **QSO's:**

—Sparsely sampled in the manner of BOSS

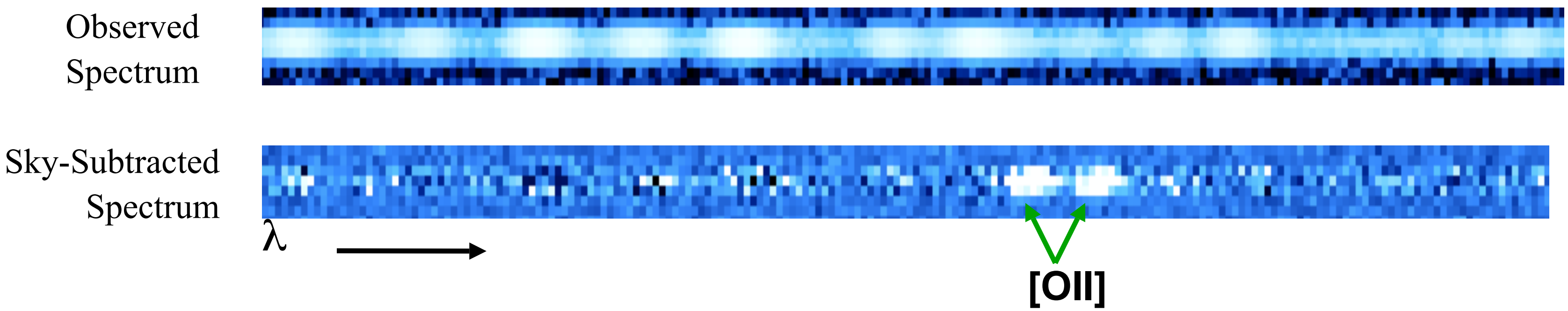
—1 million sightlines from 2<z<3.5

Question #3

Q: What line flux sensitivity do you expect as a function of wavelength in a one-hour exposure (for all redshifts in the survey)? What comoving number density of galaxies as a function of redshift will the survey sample?

Instrument designed to be a "BAO spectrograph"

Detect emission-line galaxies at z=0.6→2.0



Advantage 1: Resolution allows working between night sky lines

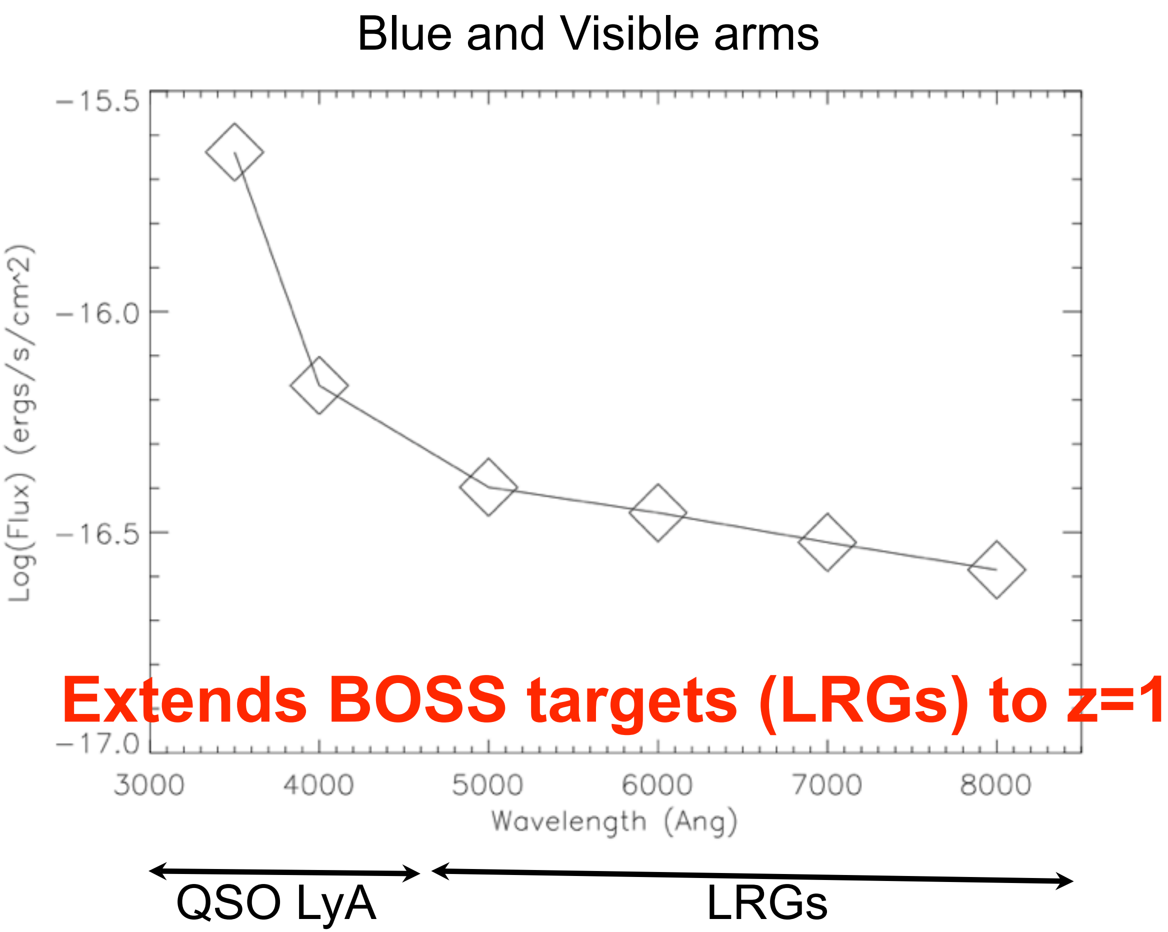
Advantage 2: High resolution splits the [OII] doublet

- Unambiguous line identification
- Doubles the chance of line measurement among bright sky lines

BigBOSS — The Ground-Based Stage IV BAO Experiment

Question #3

Single-line minimal detectable line flux (MDLF), 8σ for BigBOSS in 30 min



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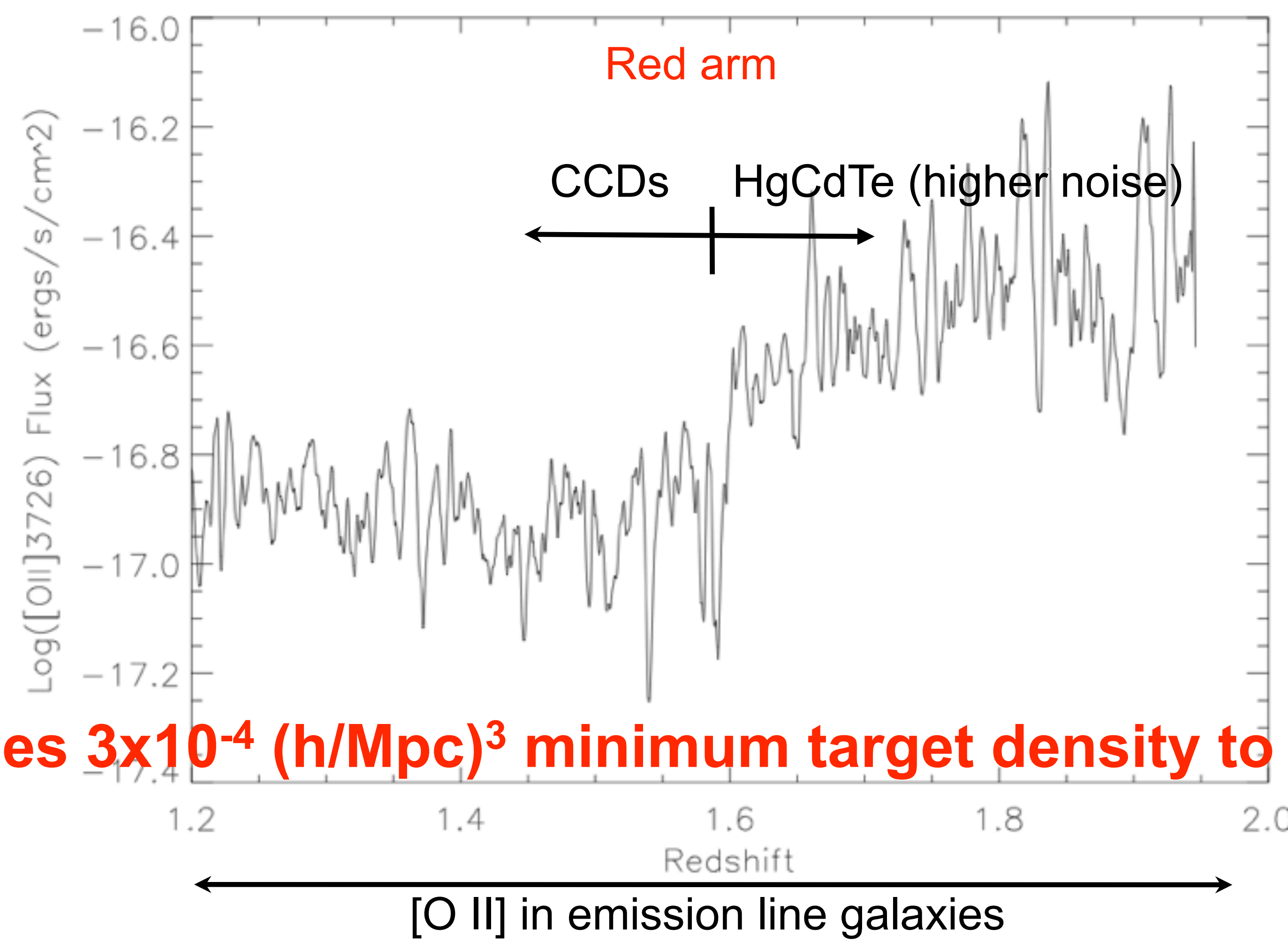
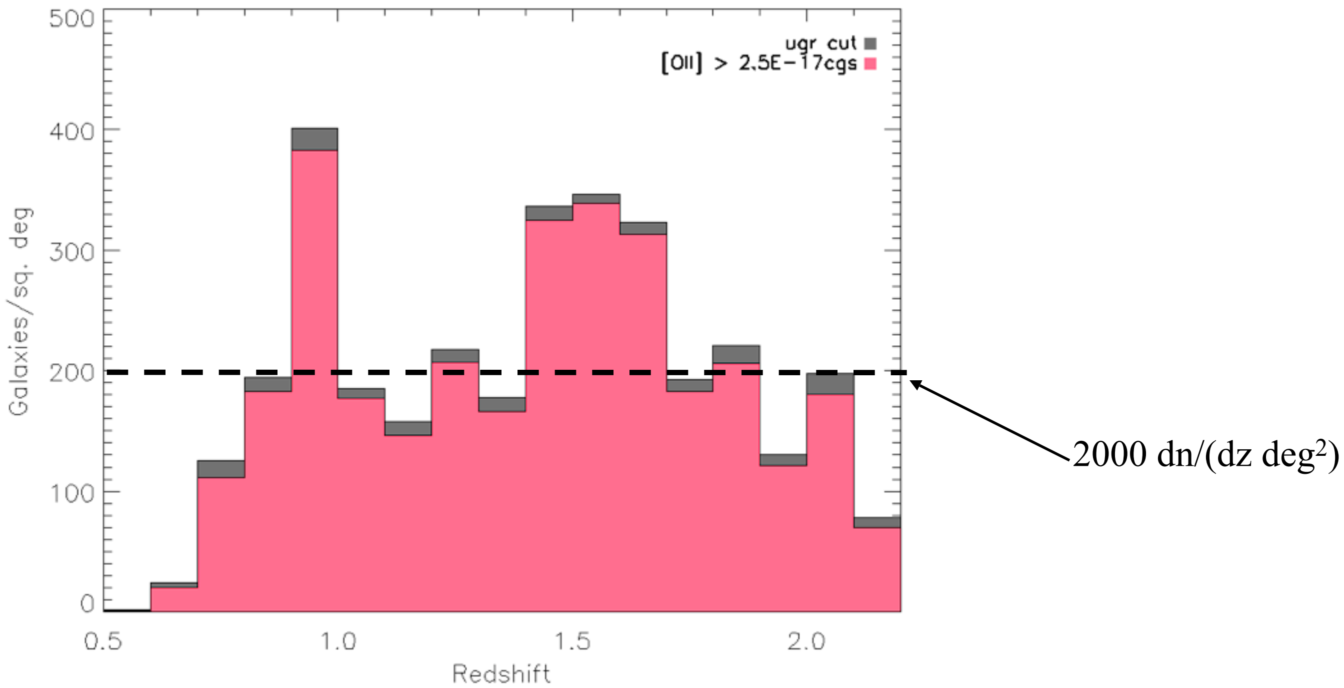
Single-line minimal detectable line flux (MDLF), 8σ for BigBOSS in 30 min



Enables 3×10^{-4} $(h/Mpc)^3$ minimum target density to z=2

Question #3

Sculpted redshift distribution for a constant number density

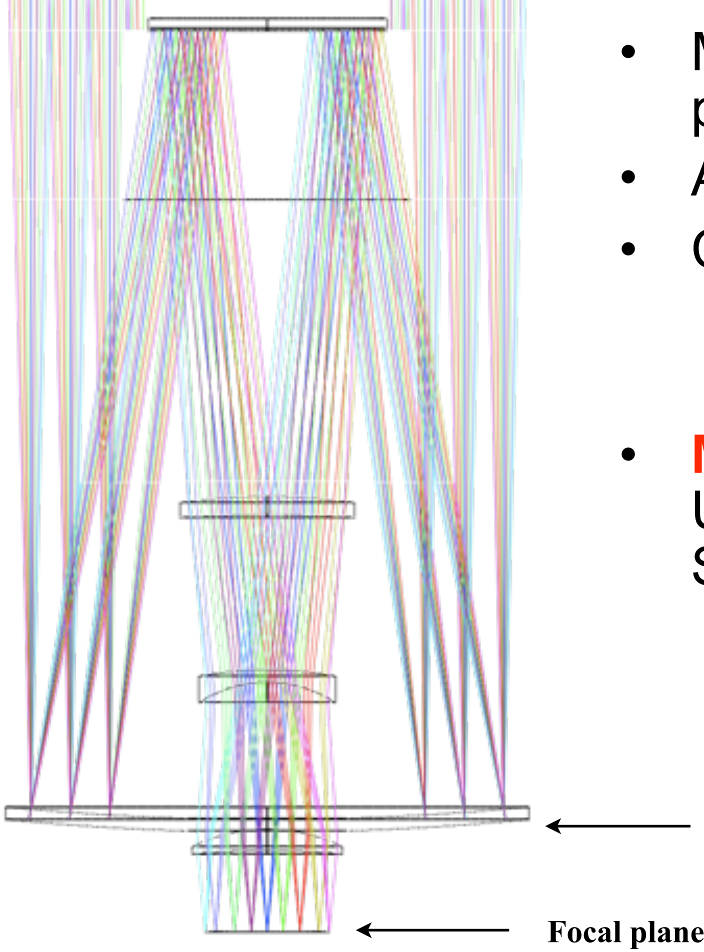


Descope option has flexibility for higher number densities at z<1.6

Sculpting makes efficient use of fibers to maximize BAO science return

Question #4

Q: How technically risky is the 3 degree field? If it is not achievable, what is the descope option and how does it modify the science achievements?



- Mayall is slow RC, making correction to 3º field possible
- All magnification is in secondary
- Corrector lenses add no power
  - *Simple fused silica*
  - *No CaF*
- **Manufacturing feasibility verified** by the University of Arizona College of Optical Sciences
  - *Less challenging than previous optics, using profilometry + interferometry*

The Ground-Based Stage IV BAO Experiment

BigBOSS

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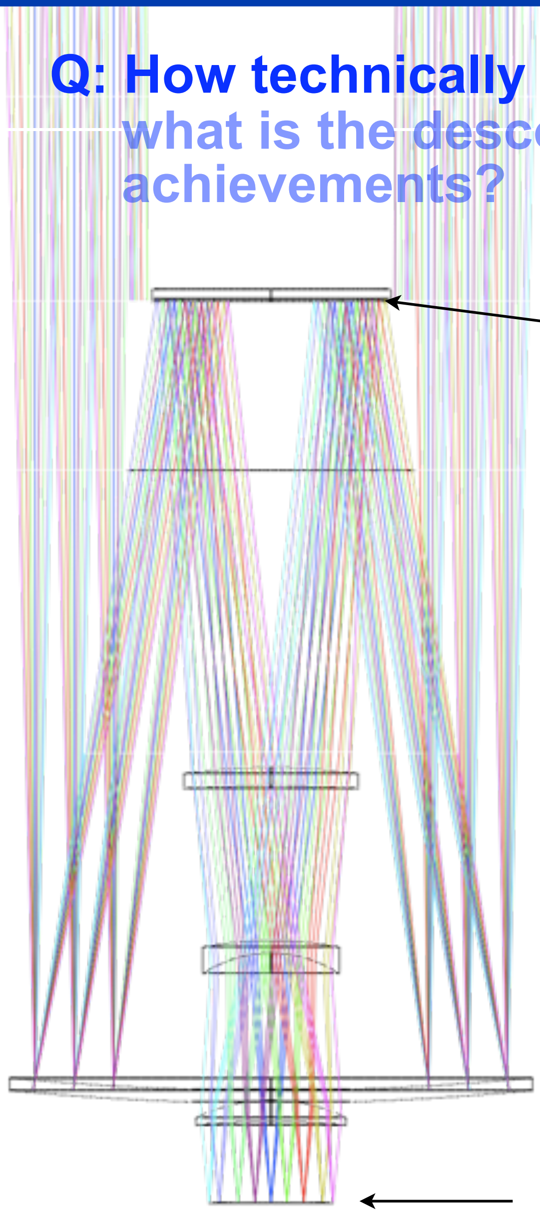


Primary mirror

Focal plane

Element		Diameter (m)	Material	Radius (m)	Aspheric departure (m)
Secondary		2.0	ULE or Zerodur	22.3	52
C1	Surf1	1.5	Fused silica	4.8	(sphere)
	Surf2			13.0	(sphere)
C2	Surf1	1.3	Fused silica	2.8	(sphere)
	Surf2			1.0	95
C3	Surf1	1.3	Fused silica	1.4	1810
	Surf2			6.2	(sphere)

Small aspheric departures low-risk

Question #4

Q: How technically risky is the 3 degree field? If it is not achievable, what is the descope option and how does it modify the science achievements?

- 2-m mirror "properly sized" with a 37% obscuration and no field-dependent vignetting
- Undersizing secondary (2-m → 1.5-m) increases vignetting at field edge to 55%

This trade could be made on cost/science; not necessary for risk

3.0 deg field (99 cm) with 1.50 cm positioners → **4000 positioners (White Paper)**
2.5 deg field (82.5 cm) with 1.10 cm positioners → **5100 positioners**
3.0 deg field (99 cm) with 1.10 cm positioners → **7300 positioners**

New baseline

5000 fibers fit

Room to be more ambitious!

Possible upscope

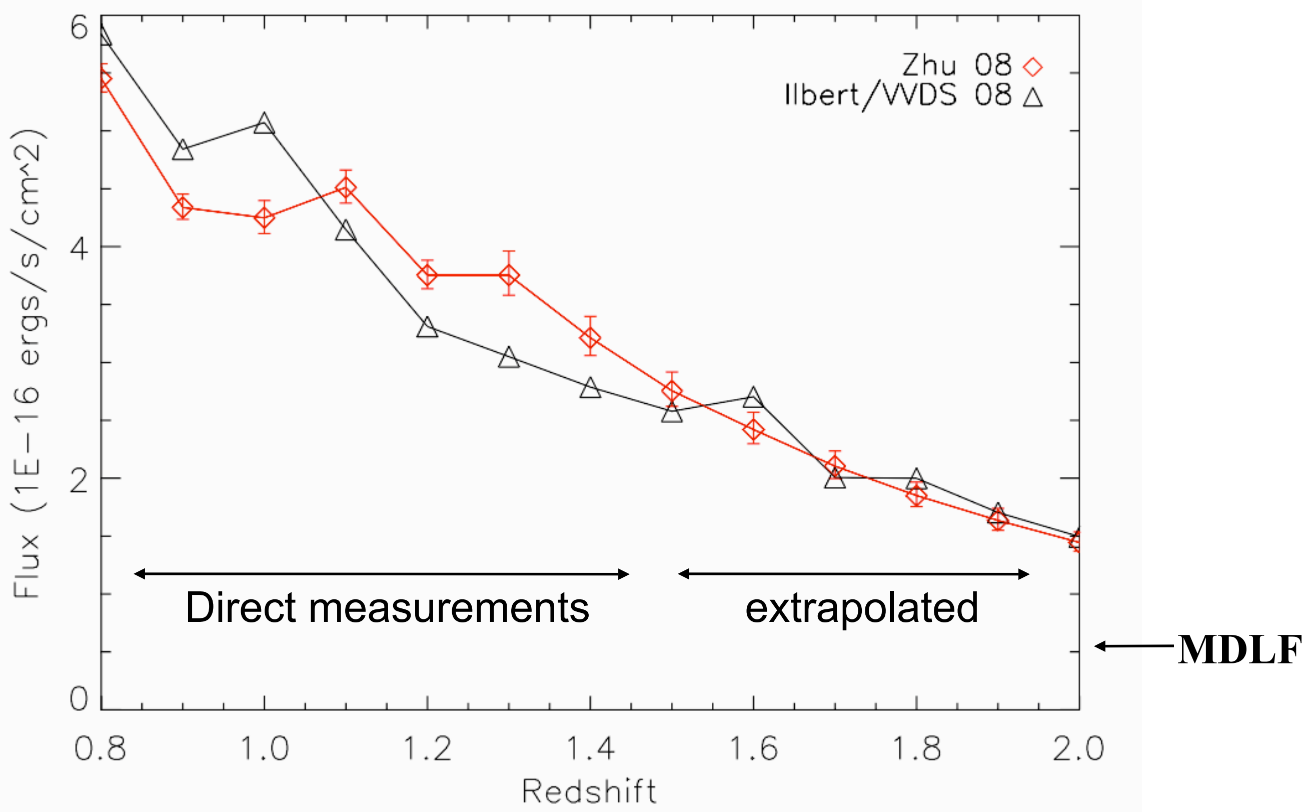
Question #5

Q: Please present a detailed estimate and justification of the accuracy of photometric redshifts in the $1.3 < z < 2$ range and the predicted OII line flux, and how it translates to object pre-selection efficiency.

- **BigBOSS does not need photo-z's for targets**
- Color cuts select late-type galaxies w/ [O II] in $1<z<2$ range
  - Targets well-studied to z=1.4 from DEEP2 + VVDS
  - Targets extrapolated to z=2.0 from zCOSMOS
  - Selection efficiency depends on *ugr* (to z=1.6) or *grz* (to z=2) depths

Question #5

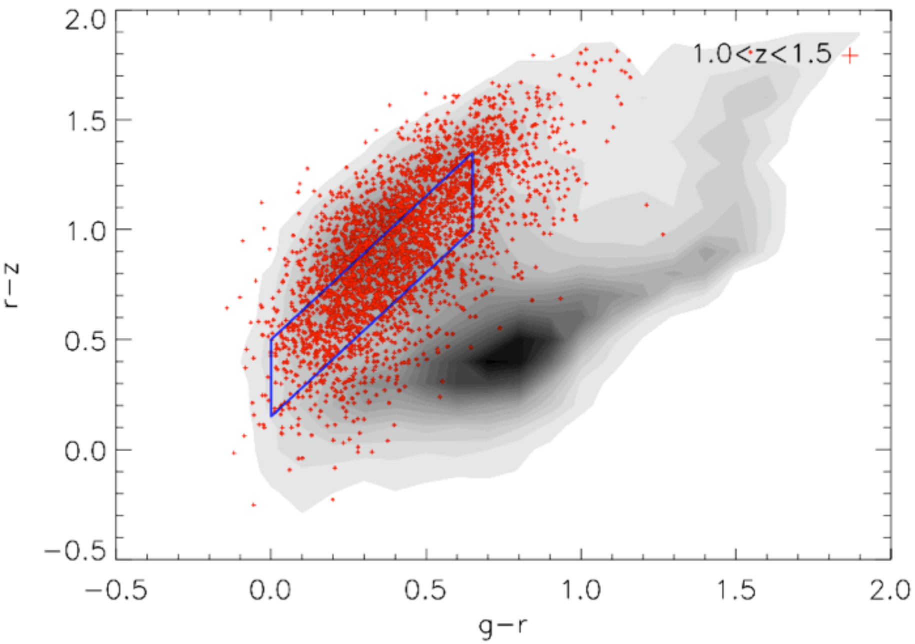
Combined [OII]λ3727 line flux limit for 2000 dn/(dz.deg^2)



- **Measured [OII] data sources** from zCOSMOS / VVDS [OII] fluxes (Ilbert, 2008) and the DEEP2 [OII] redshift survey (Zhu, 2008)
- Conservative [OII] minimum detectable line flux (MDLF) of 2.5E-17 ergs/s/cm^2 ($F_{[OII]}$=1E-16 cgs flux at z=2, factor of 2 for split [OII], factor of 2 for margin)

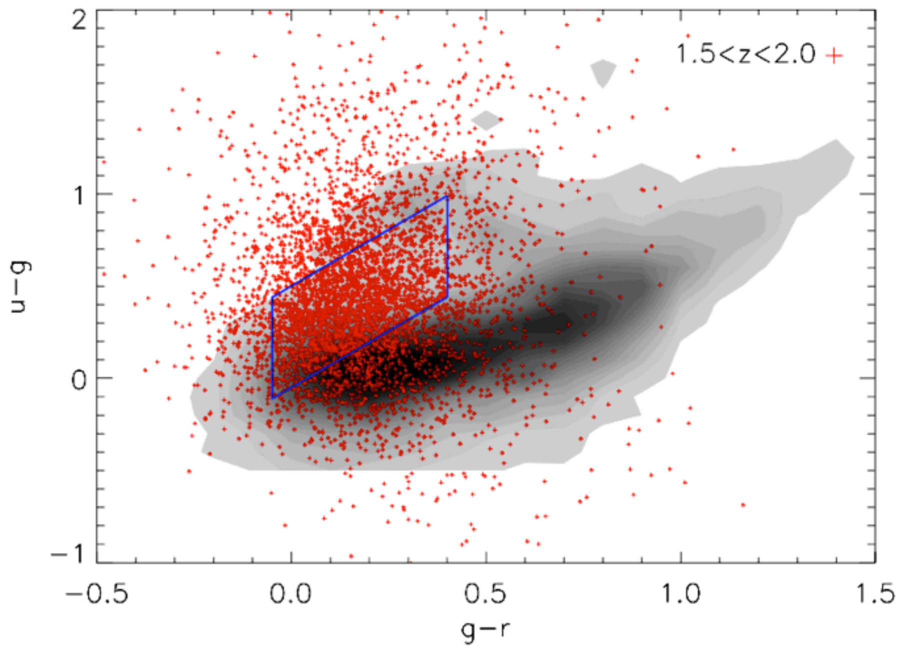
Question #5

z<1.6 sample
grz-selected



PTF *g*+*r* bands
+ PanSTARRS-1 *z*-band

1.5<z<2 sample
ugr-selected

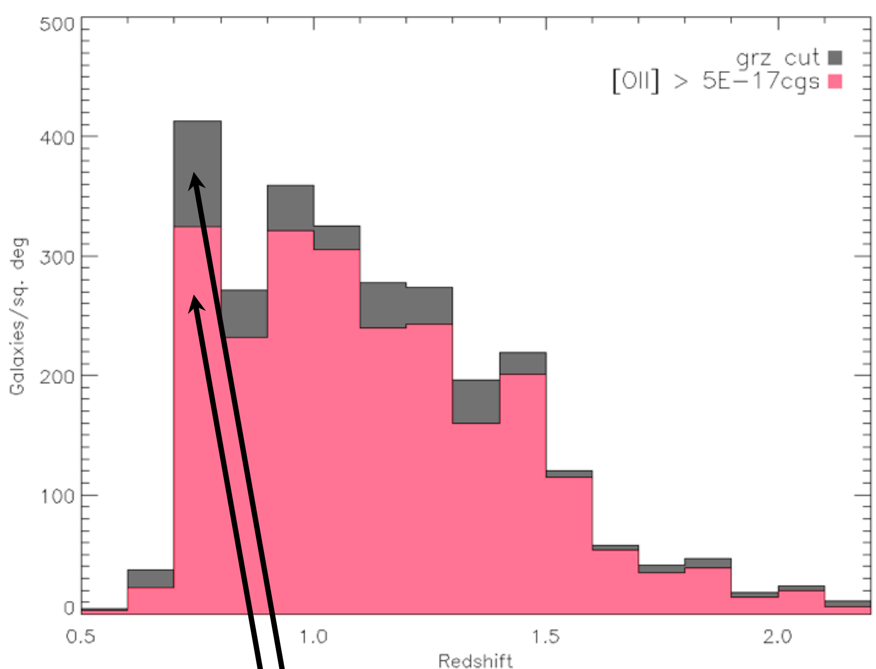


PTF *g*+*r* bands
+ CFHT *u*-band (proposed)

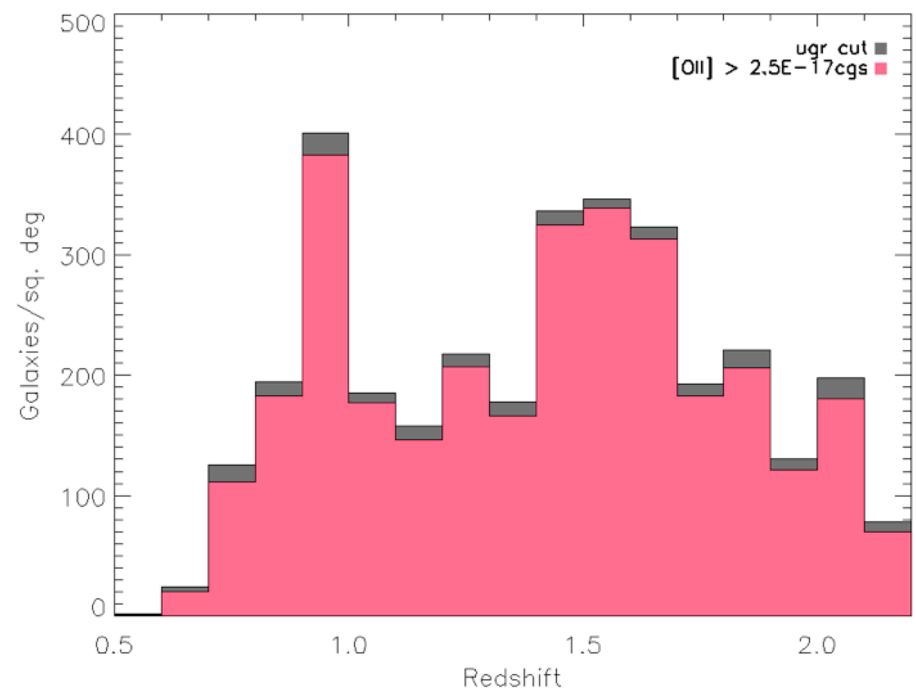
Synthetic magnitudes are degraded using photometric errors from Palomar Transient Factory (*gr*), Pan-STARRS-1 (*iz*), and a CFHT-like survey (*u*)

Question #5

z<1.6 sample
grz-selected



1.5<z<2 sample
ugr-selected



Galaxies satisfying color-mag cuts

... and detectable [O II] emission

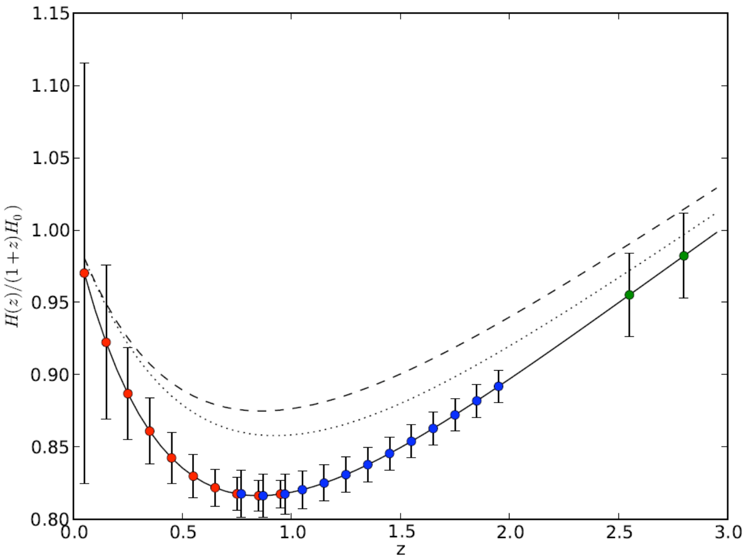
zCOSMOS and DEEP2 demonstrate large fraction of bright em lines at z>1

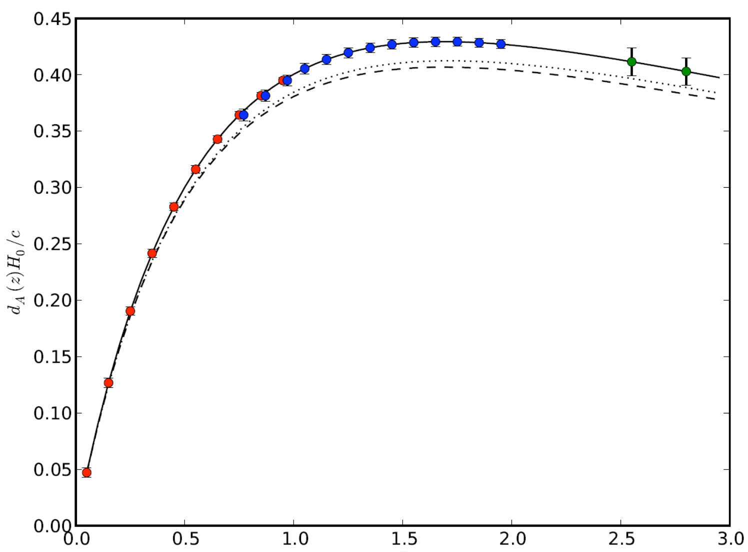
BigBOSS: The Stage IV BAO Experiment
Conclusions

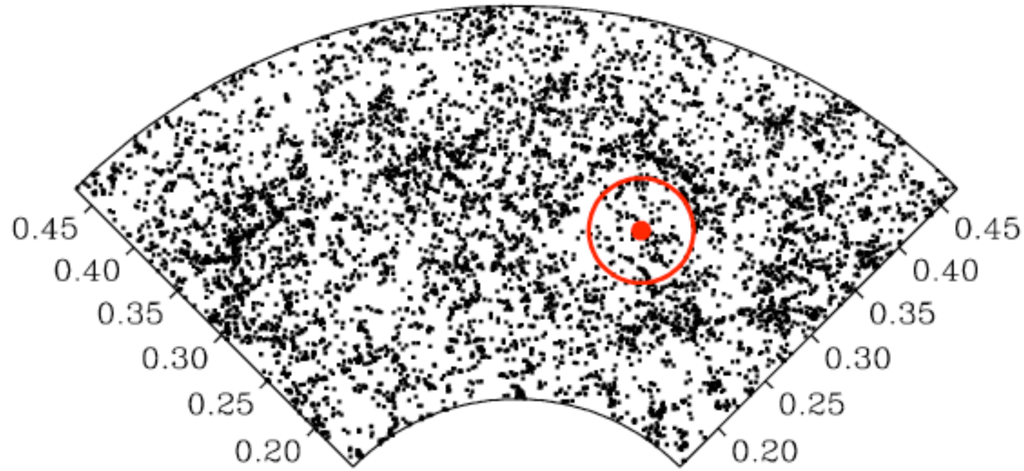
- **"Stage-IV" dark energy experiment from the ground**
- **Higher scientific performance than JDEM-BAO**
- **Lower science risk than JDEM + greater flexibility**
- **Enhances future imaging surveys (DES, LSST)**
  - Adds spectroscopic capability, eg. for SNe follow-up
  - Calibrates LSST photo-z's for WL
- **Requires only 4-m telescope time**
  - North: Kitt Peak (4m)
  - South: CTIO (4m)

Backup Slides

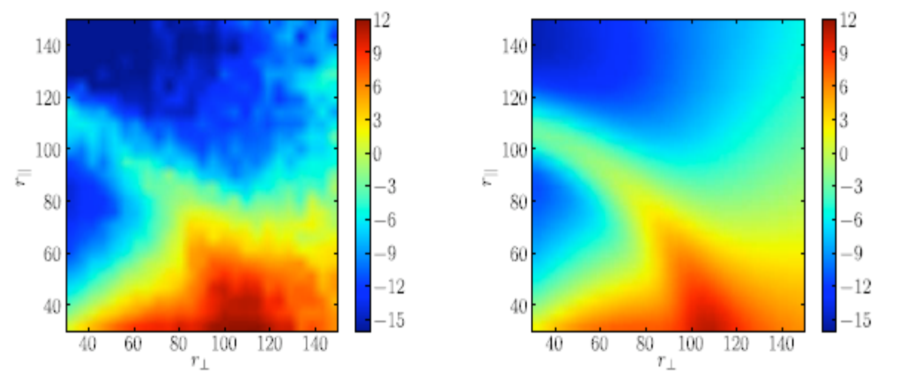
BAO:
Geometric probe of dark energy





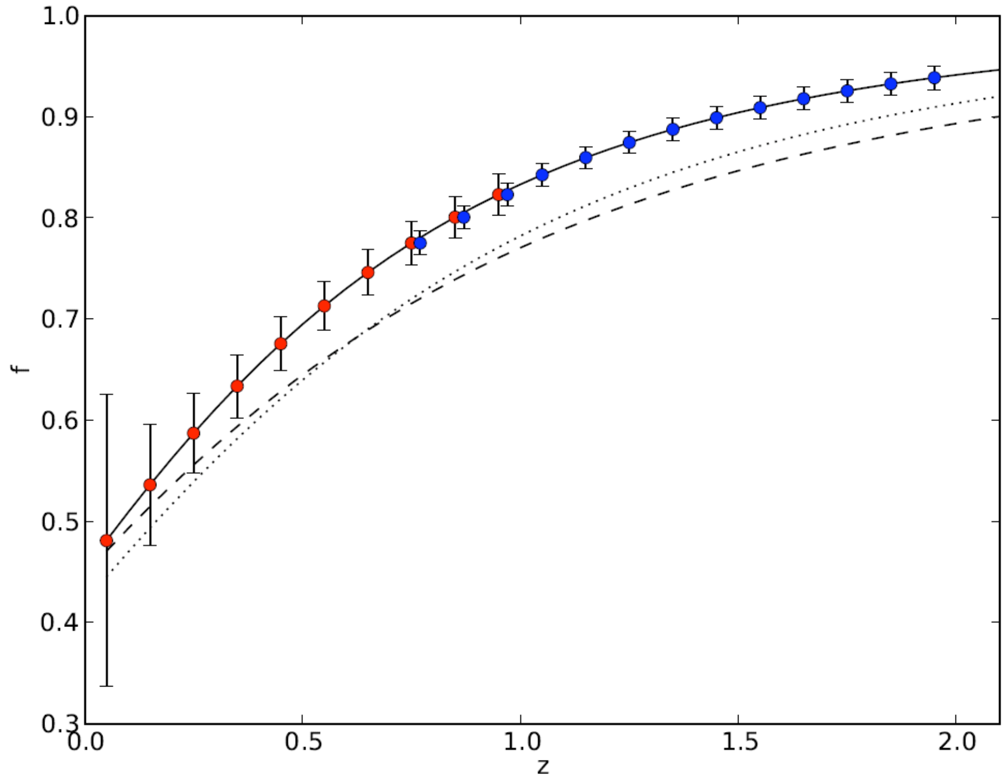


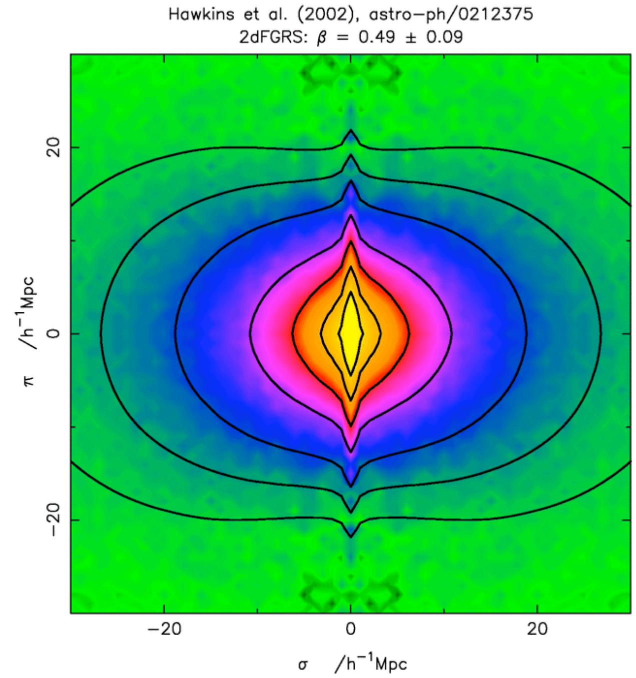
BAO scale in SDSS galaxies.



BAO in Lyman-Alpha (Slosar et al in prep.)

Redshift-space distortions: Gravitational probe of dark energy

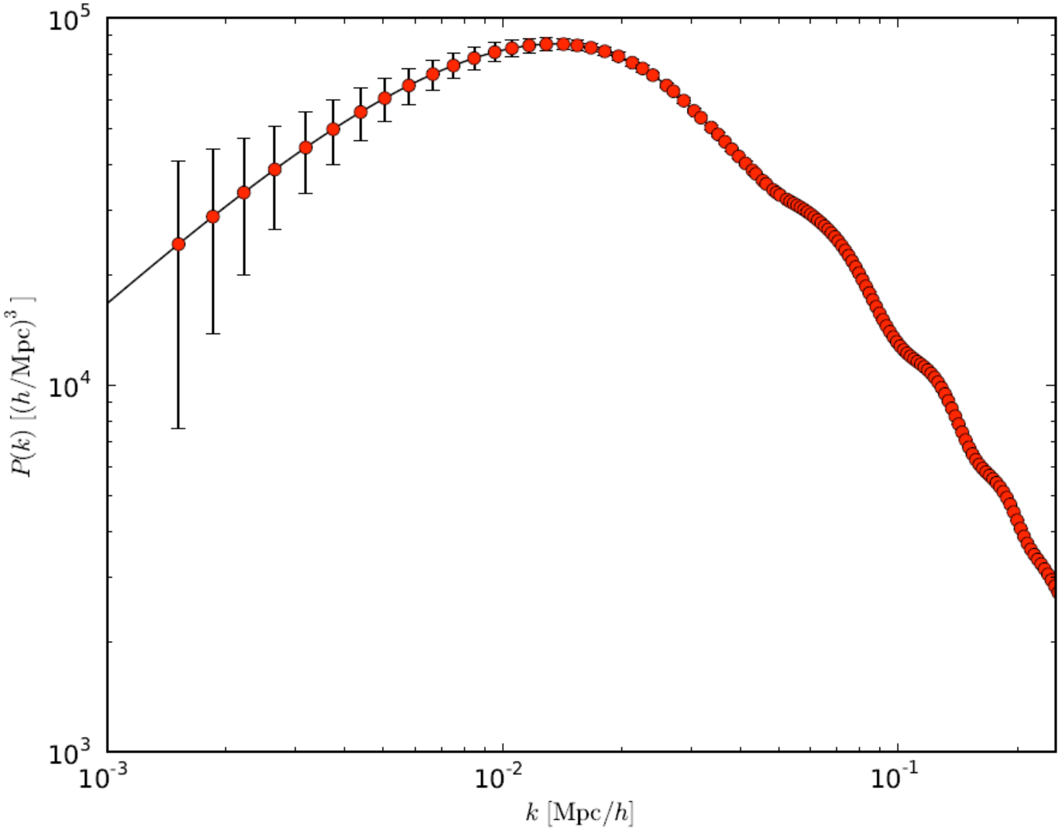




- Competitive with BAO
- Relatively conservative estimates of error bars
- Probes growth of fluctuations rather than geometry

The Ground-Based Stage IV BAO Experiment BigBOSS

BigBOSS: Linear power spectrum



Preliminary:
Errors assume Gaussianity and no systematics

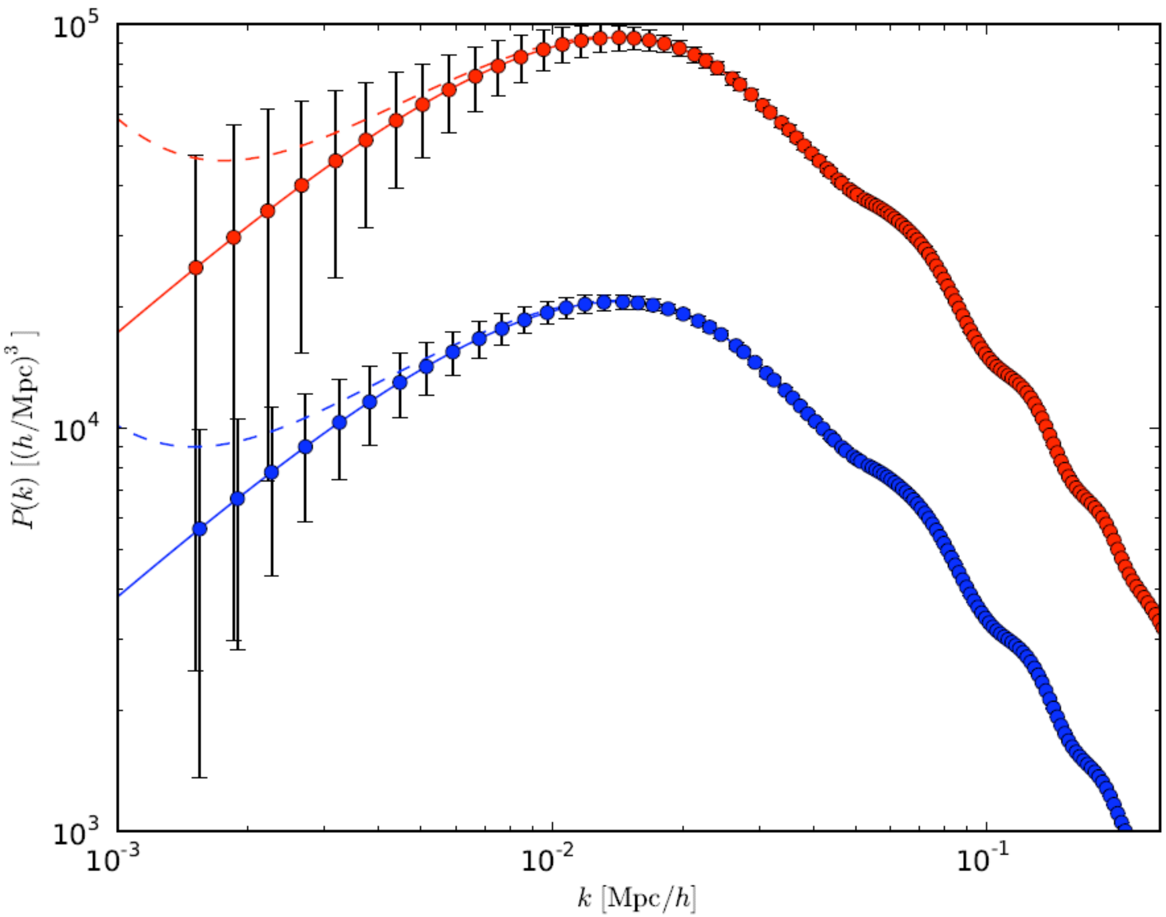
- Significant improvements in cosmological parameters from the shape of the linear power spectrum
- Guaranteed detection in several areas (N only, with Planck):

Neutrino mass	**0.019 eV** **0.018 eV for JDEM** **(current knowledge >0.05 eV)**
Number of relativistic species	**0.12** **0.11 for JDEM**
Curvature	**0.0006** **Factor 10 better than Planck** **0.0005 for JDEM**
Spectral index / running	**0.0030/0.0018** **Factor 6 better than Planck** **0.0028/0.0017 for JDEM**

The Ground-Based Stage IV BAO Experiment

BigBOSS

BigBOSS: Non-gaussianity and f_{NL}



- Induces scale-dependent bias
- Big Volume helps!
- Interesting region around $f_{NL} = 1$
- Dashed lines predictions for $f_{NL} = 5$
- Systematics controlled by having multiple samples with different biases
- Selection function under control

BigBOSS allows systematics checks w/ multiple samples

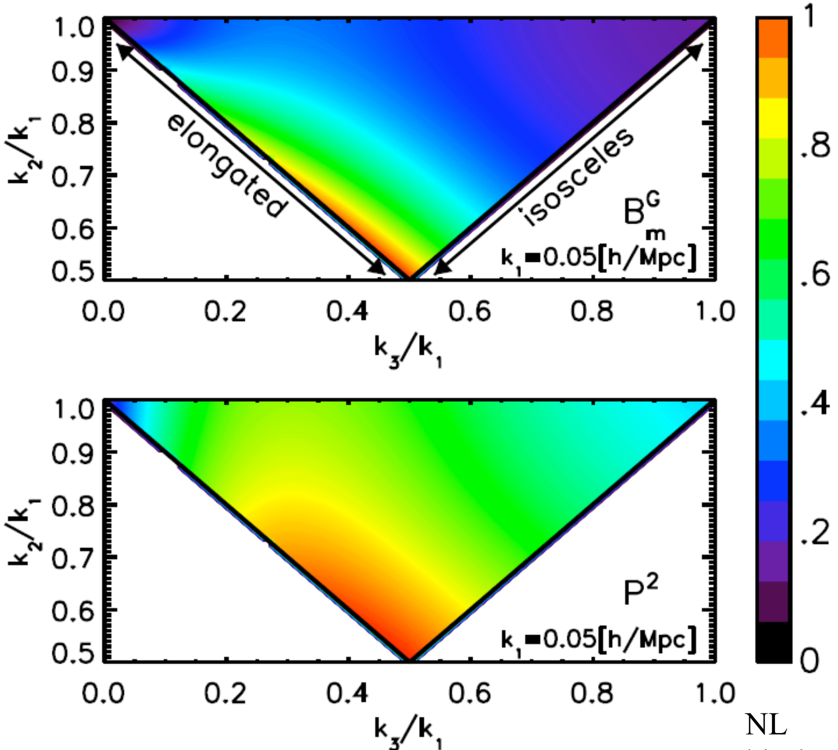
JDEM-BAO lacks this

The Ground-Based Stage IV BAO Experiment
BigBOSS

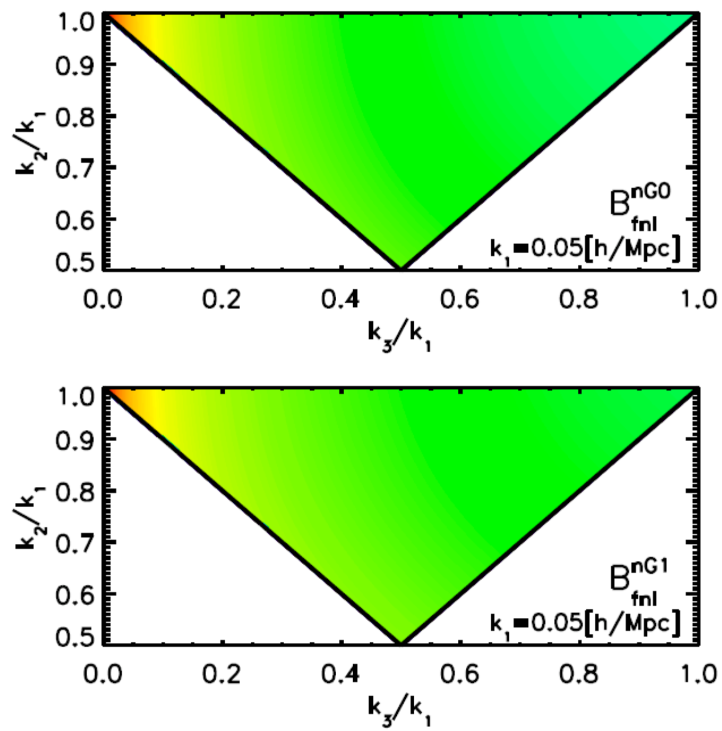
BigBOSS: Bispectrum

- Has big potential, in principle:
  - Measures **GROWTH -- yet another dark energy probe**
  - Can measure more general types of non-Gaussianity
  - Large scales implies better behaved sample than e.g. SDSS
  - Different contributions separated by different triangle configurations
  - Plots from Jeong and Komatsu:

NL grav. evolut.



NL biasing



Non-Gaussianity induced

The Ground-Based Stage IV BAO Experiment
BigBOSS

BigBOSS and weather

Can weather screw the Big Boss?

Weather causes variations in depth and completeness
Can result in fluctuations in galaxy density field

Can BigBoss screw the weather?

Yes, because:

- Exposure times tuned to S/N
  - *As done for SDSS, BOSS*
- Weather-induced fluctuations are transversal
  - Small number of modes can be marginalized
- CMB experiments have “rain gauges” and everybody believes CMB

The Ground-Based Stage IV BAO Experiment

BigBOSS

BigBOSS and “double-dipping”

Two samples: LRGs + ELGs from $0<z<1$

Two samples populate different halos / different bias

Superior systematics control

Directly compare:

- BAO scales derived from two samples
- RSD results derived from two samples
- Linear power spectra from two samples
- Non-gaussianity from two samples
- Cross-correlation coefficients of two samples: directly measure stochasticity

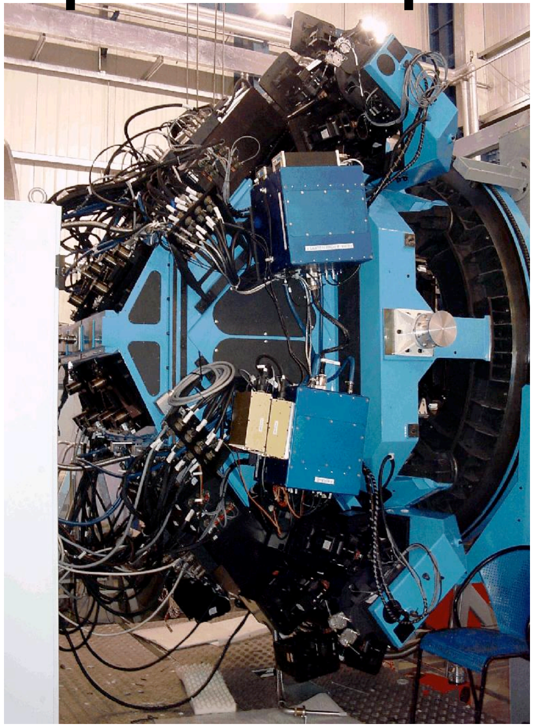
No other proposed experiment has this capability

The Ground-Based Stage IV BAO Experiment
BigBOSS

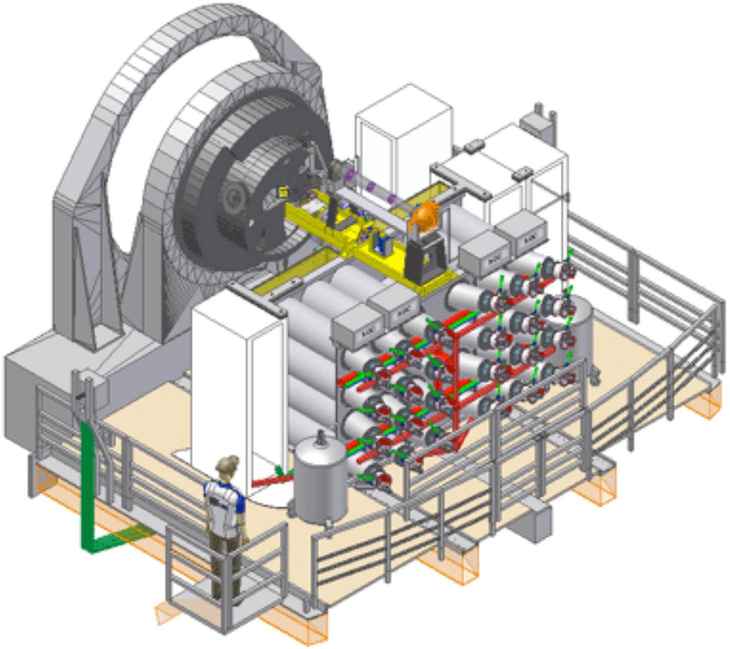
French participation

French expertise in spectrographs

VIMOS



MUSE

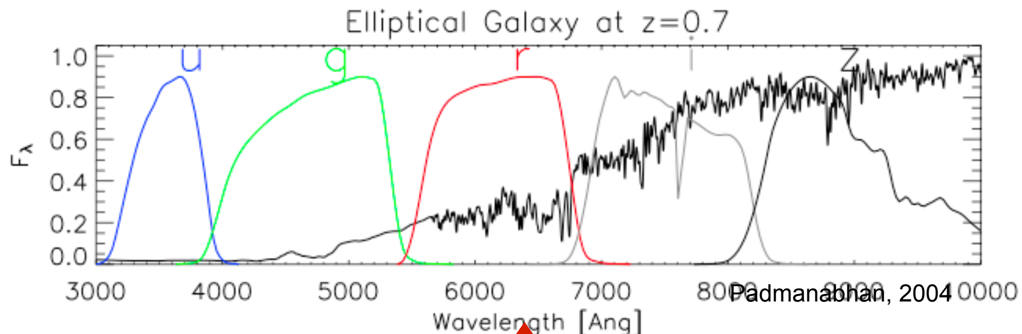


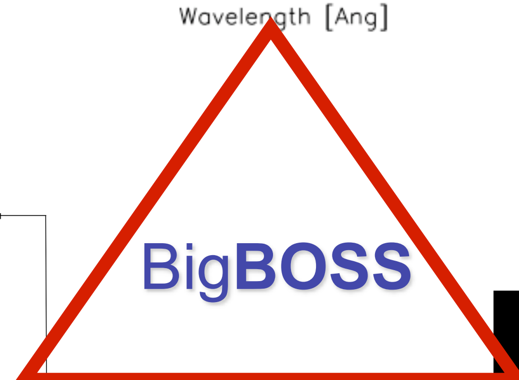
24 spectrographs
24 detectors

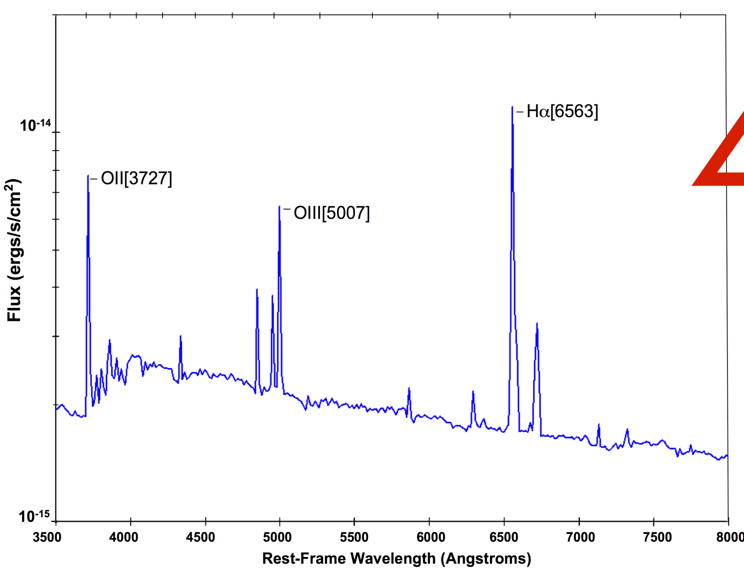
The Ground-Based Stage IV BAO Experiment
BigBOSS

Spectroscopic Targets

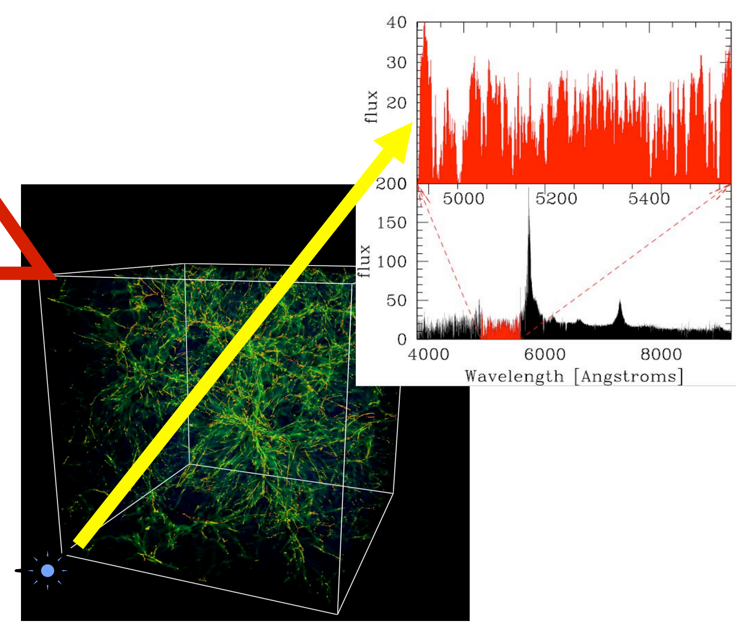
0.2<z<1: Luminous Red Galaxies (extend BOSS footprint & z)







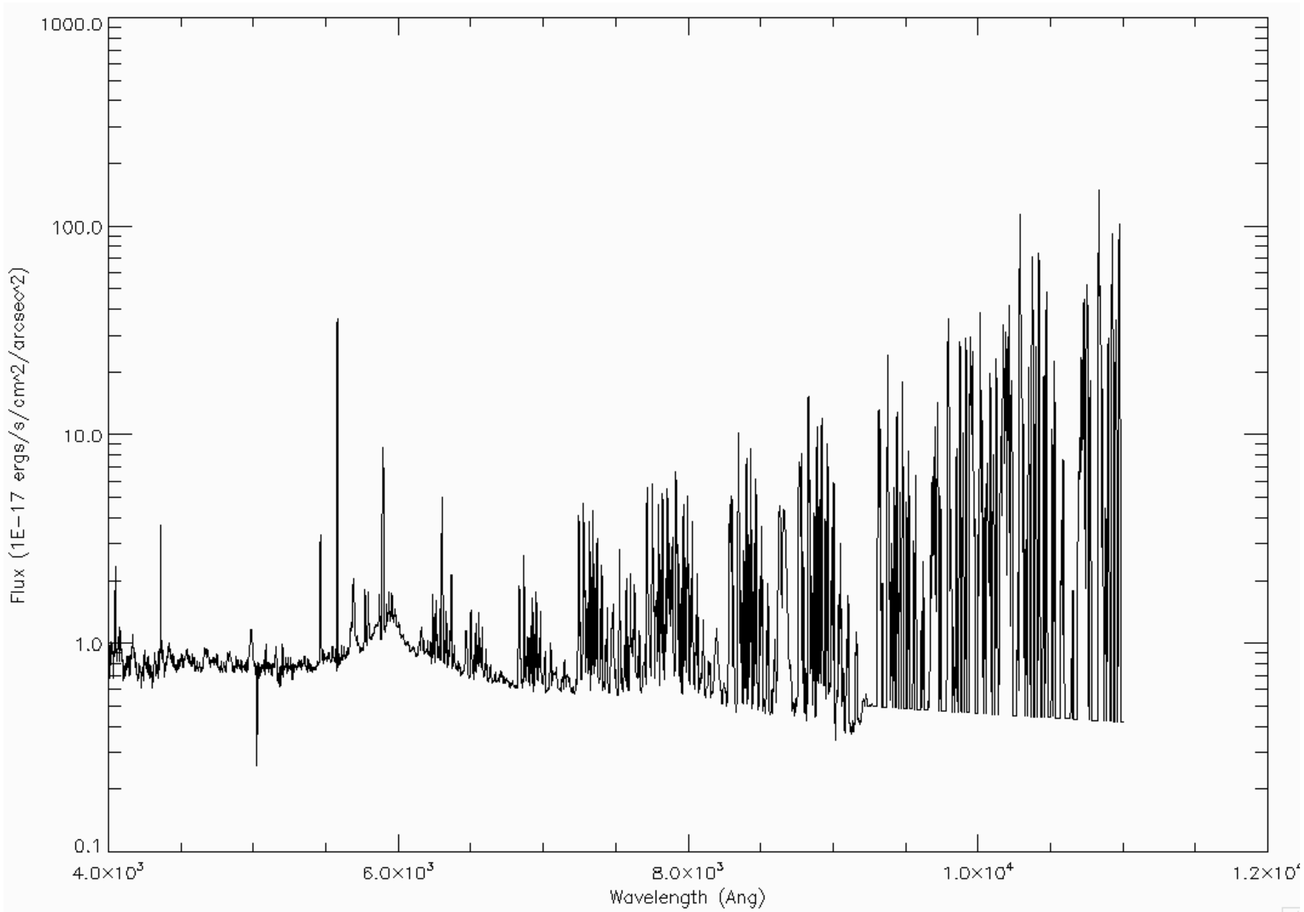
1<z<2: Emission line galaxies



2<z<3.5: Lyα forest from QSOs
(pioneered from BOSS)

The Ground-Based Stage IV BAO Experiment
BigBOSS

Sky Background



- **Sky background from Gemini w/ continuum scaled to SDSS (conservative)**
  - **Slightly conservative relative to DEEP2 DEIMOS spectra**

BigBOSS: The Stage IV BAO Experiment Science Reach vs. JDEM

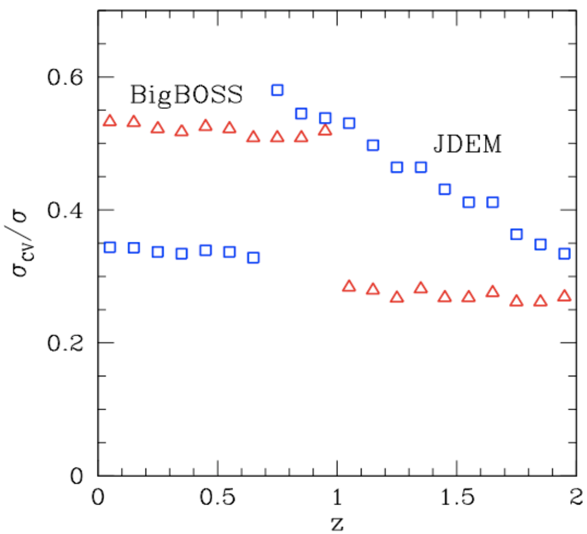


Figure 1a: Distance accuracies in z=0.1 bins for BigBOSS (red) and JDEM (blue) normalized to the cosmic variance limits. These forecasts were based on the Seo & Eisenstein (2007) Fisher matrix formalism and assume a 50% reconstruction of the acoustic feature.

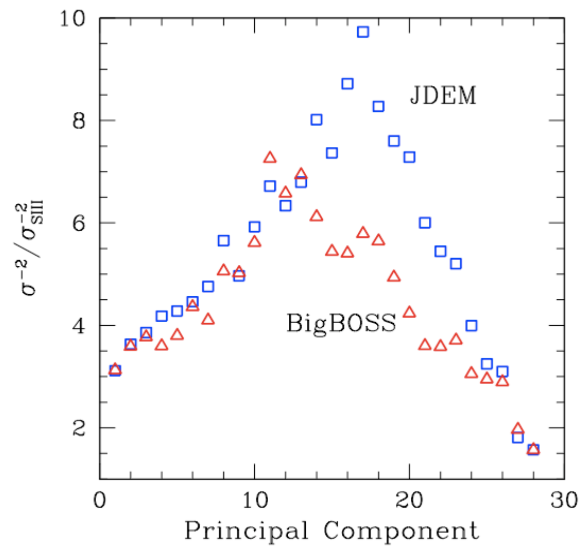
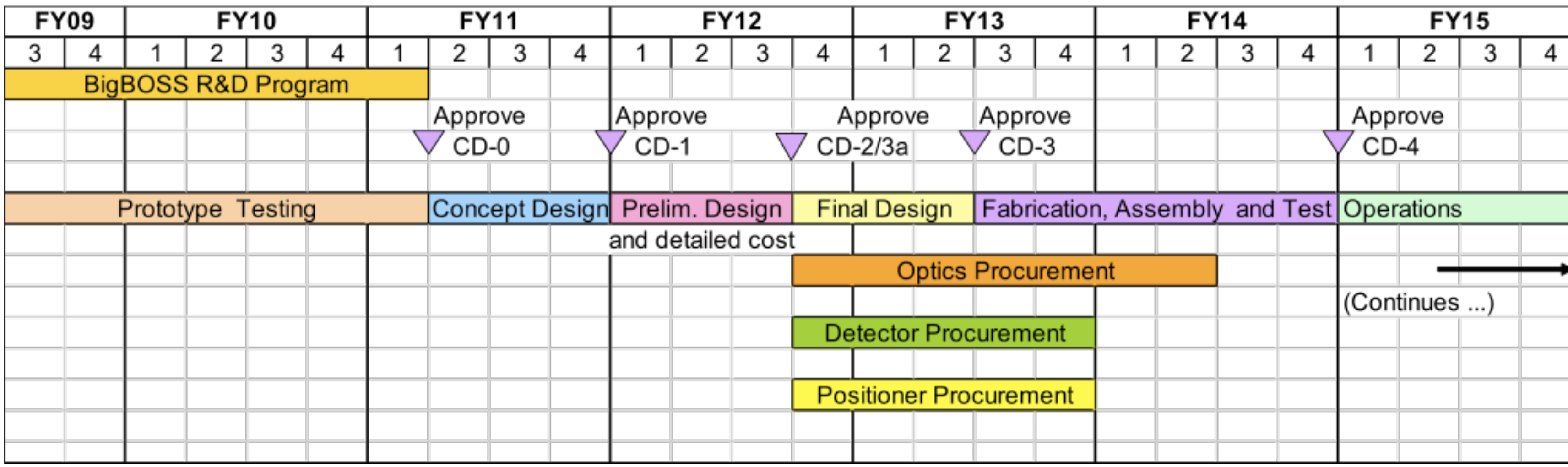


Figure 1b: The inverse variance on the first 30 principal components of the evolution of the dark energy, as defined by the Figure of Merit Science Working Group (FoMSWG). The variances have been normalized to the pre-JDEM Stage III forecasts made by the FoMSWG.

BigBOSS: The Stage IV BAO Experiment Timeline



R&D activities supported by LBNL engineering and technical labor

CD-0 assumed FY11 Q1